NASA TT F-748

Ye.Ts. Andreyeva-Galanina,
S.V. Alekseyev, A.V. Kadyskin
and G.A. Suvorov

NOISE AND NOISE SICKNESS

Translation of "Shum i shumovaya bolezn1"
Leningrad, "Meditsina" Press, 1972.

TRANSLATED FROM RUSSIAN

National Aeronautics and Space Administration
Washington, D.C. 20546, July 1973

1. Report No. NASA TT F-748	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle NOISE AND NOISE SICKNESS		5. Report Date July 1973 6. Performing Organization Code
7. Author(s) Ye. Ts. Andreyeva-Galanina, S.V. Alekseyev, A. V. Kadyskin and G. A. Suvorov		8. Performing Organization Report No. 10. Work Unit No.
9. Performing Organization Name and Address SCITRAN, P.O. Box 5456 Santa Barbara, Cal. 93108		11. Contract or Grant No. NASW-2035 13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Shum i shumovaya bolezn'" Leningrad, "Meditsina" Press, 1972, 304 pages

16. Abstract Basic concepts and questions about noise, which contribute to a proper understanding of the characteristics of industrial noise as well as an experimental acoustical complex for the study of the noise factor, are examined.

Much of the work is devoted to material characterizing the effect of noise (various parameters, continuous and interrupted noise) on the human organism. Special attention has been given to the effect of noise on the organ of hearing. Important data pertain to physiological research, including the questions of adaptation and fatigue. Changes in occupational hearing losses, caused by the prolonged effect of noise, are discussed. Data are given on the effect of an acoustic stimulus on the eye, motor analysor, on vibration sensitivity and the functional state of the vestibular analysor, involuntary functions, and the cardio-vascular system.

The authors' own data about the effect of noise on the functional state of the central nervous system are presented. It is concluded that both reactivity and lability of the cortex and subcortical structures are reduced, evidently in proportion to the noise effect. The degree of these effects is determined by the force of the noise.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unlimited - Unclassified

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
		338	$6.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

PRECEDING PAGE BLANK NOT FILMED

ANNOTATION

/2*

This book contains basic concepts and questions about noise, which contribute to a proper understanding of the characteristics of industrial noise as well as an experimental acoustical complex for the study of the noise factor.

The largest part of the work is devoted to material characterizing the effect of noise (various parameters, continuous and interrupted noise) on the human organism. Special attention has been given to the effect of noise on the organ of hearing. This section contains some important data pertaining to physiological research, including the questions of adaptation and fatigue. Changes in occupational hearing losses, caused by the prolonged effect of noise, are discussed. Data are given on the effect of an acoustic stimulus on the eye, motor analysor, on vibration sensitivity and the functional state of the vestibular analysor, involuntary functions, and the cardio-vascular system.

Even more important are the authors' own data about the effect of noise on the functional state of the central nervous system. In this section it is concluded that both reactivity and lability of the cortex and subcortical structures are reduced, evidently in proportion to the noise effect. The degree of these effects is determined by the force of the noise.

The authors have made a valuable contribution to the present understanding of those biochemical changes in the central nervous system which are caused by noise. The fact that pulsed and stable noise affect tissue respiration of the cerebral cortex has been established: pulsed noise (especially nonperiodic) has an especially unfavorable, irritating effect.

*Numbers in the margin indicate pagination in the original foreign text.

The book gives the first systematic description of noise sickness, distinguishing specific clinical syndromes. The authors emphasize that clinical symptoms of the effect of noise can be subdivided into specific symptoms, which develop in the Corti organ, and nonspecific symptoms — in various organs and systems of the organism.

In conclusion, measures are suggested for the prevention of the harmful effect of noise and medicinal prevention.

The book is intended for physicians in various specialties, as well as for engineering and technical workers involved in combatting noise.

The monograph contains 73 illustrations and 51 tables. The bibliography cites over 430 literature sources.

FOREWORD

During the entire course of his phylogenetic evolution, man has lived in a world of various sounds. These surround man anywhere and everywhere; he lives amid them, sometimes not even hearing them. He has learned to distinguish dangerous from safe sounds; some cause positive emotions, others, on the other hand, depress the psyche and stimulate the nervous system. Leaving the city in clear, windless weather, we are struck by the quiet. But this quiet is relative. As we move, particles of air all around us start to vibrate. These vibrations extend in all directions, they become diffused, are weakened and fade, are again strengthened, creating a definite sound background.

In the process of his phylogenetic development and adaptation to the outer world, man has learned to distinguish the nature of individual sounds. Sounds of the natural world surrounding us have the same frequencies, of which a frequency of about 1000 Hz is always present (according to data of the Acoustical Laboratory of Moscow State University); these sounds occur in the sensitivity zone of the ear. The structure of the ear, sensing sounds and a complex of them, differentiates one vibration from another as well as human voices. It detects their gradations, one word from another. The world of sounds allows us not only to enjoy them in nature surrounding us, but also to hear musical compositions and to communicate with each other. Unfortunately, sounds often also cause negative emotions, cause sickness, and sometimes also bring psychic trauma. A confused complex of sounds, creating a special sound background, often of considerable intensity, is for people a stress, leading to the development of a unique "sickness of modern life." The psyche also sometimes suffers from the latter, and people must be protected from it.

The development of cities, the creation of new mechanized means of transportation, growth and progressive development of modern industrial technology, the creation of multi-cycle, high-powered equipment increase the intensity of noise, broaden the range of frequencies, and complicate their character. Noise becomes dissimilar to /4
that which man has been accustomed in the past. In the Middle Ages there was noise only in certain workshops, and in the time of the English Queen Elizabeth even noise "from playing the pipes" disturbed the rest of the population. Today when cities are filled with traffic and industries, noise is an extremely negative environmental factor.

Regarding noise in Paris, it has been shown that at 5 p.m. at Place St-Augustin it could drown out the noise of Niagara Falls, but one motorcycle, traveling along the streets of Paris at 3 - 4 a.m., can wake up 900,000 inhabitants. And so it goes in many cities of the world. Noise has become an enormously important social factor, causing considerable damage to the human organism. It is therefore not surprising that the fight against noise is a most important problem, attracting the attention of a wide range of people. Acoustics laboratories have been established in research institutes and colleges (medical, humanities, technical).

Although in capitalistic countries little importance is attached to the battle against noise, and only a few individual groups of scientists are waging it with workers in a few industries, in the USSR this question has been placed on the level of State undertakings. Various experts are involved in its solution — design engineers, acoustical physicists and hygienists. Workers play an important role in combatting noise by often giving valuable information, as they are well acquainted with the noise background of their machines.

In order to combat noise properly, it is necessary to understand its physical characteristics and its effect on the organism. Noise, as a powerful environmental stimulus, causes significant changes in the functional state of the organism and results in a new ailment of modern life — noise sickness.

A great deal of experimental data and clinical observations have been accumulated in the past ten years making it possible to approach the evaluation of noise on the organism in a new way, to determine its important characteristics,

spectral composition and intensity, to detect processes occurring deep in the central nervous system and the pathogenesis of the development of individual symptoms and syndromes.

The section on clinical observation of noise sickness was written in collaboration with E. A. Drogichina, L. Ye. Milkov and N. N. Shatalov.

The authors hope that the book will be of use to specialists in various areas of medicine and technology.

Prof. Ye. Ts. Andreyeva-Galanina

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS

CHAPTER I

PHYSICAL AND HYGIENIC CHARACTERISTICS OF NOISES (INDUSTRIAL), THEIR MEASUREMENT AND STANDARDIZATION

Physical Characteristics of Noise

By noise we usually mean a complex of sounds, unfavorably affecting the human organism, disturbing his work and rest. From the physical point of view, sound and noises are wave-like oscillatory propagations of particles of an elastic medium; noise is, as a rule, irregular, random vibrational processes.

Sources of noise are vibrating solid, liquid or gaseous bodies. Usually the vibrating body is in an elastic medium and excites mechanical vibrations which displace particles of the medium (air) in the layer directly adjacent to the surface of the vibrating body. They are rhythmically compressed and dilated. Because of inertia and the elasticity of the medium, these compressions and dilatations are transmitted to neighboring particles, with the result that sound vibrations are spread in the free external environment.

Sounds which are diffused in the air are called air sounds, and vibrations diffused in solid bodies are known as structural sound or noise. The greater the amplitude of vibration of the sounding body, the greater the amplitude of the sound pressure and the corresponding force of sound or noise.

Sound pressure is the variable pressure which develops in addition to atmospheric pressure in a gaseous or liquid medium when sound waves pass through it. Sound pressure is designated by the letter p and is expressed in dynes per 1 cm^2 or newtons per m^2 (a newton is a force which imparts to a body with a constant mass of 1 kg acceleration of 1 m/sec^2). In the compression phase, sound pressure is positive, but in the dilatational phase it is negative. The dynamic range of sound pressure perceived by the human ear is $2 \cdot 10^{-5} - 2 \cdot 10^2$ N/m^2. Under industrial conditions, these excess sound pressures in the medium develop with mechanical vibrations in frictional surfaces, with the mutual collision of separate parts, with vortices, etc.

In simplest form, sound vibrational movements follow a sinusoidal law, whose oscillograph recording has the shape of a sinusoid. One of the basic characteristics of the vibrational movement is the law governing its change in time. The time during which the vibratory body makes one complete oscillation is called the period of oscillation (T) and is measured in seconds. /6

The number of complete oscillations completed in one second is called the frequency of oscillations (f). The unit of measurement of frequency — hertz (Hz) — is equal to one oscillation per second. Frequency of oscillations determines the pitch of a tone. The higher the frequency of oscillations, the higher the tone of the audible sound. The period of oscillations and the frequency are related by the ratio

$$T = \frac{1}{f}.$$

The maximum deviation of the vibratory body or the maximum deviation of pressure from an equilibrium position in dilatation or compression is called the amplitude of oscillation. In view of the fact that sound pressure cannot develop without the movement of particles, in determining the characteristics of the field, measuring the vibratory rate of the particles is very important, i.e., determining the instantaneous value of the speed of the vibratory movement of particles of the medium when a sound wave is propagated in it (unit of measurement — m/sec).

The distance in which the wave process can be propagated in one second is called the velocity of sound (C). In most media, the velocity of sound depends on the elasticity and density of the medium, and does not depend on the vibration

frequency of the sound source, i.e., there is a constant value for fixed parameters of the medium. In air with a temperature of 20° C and normal atmospheric pressure, it is 334 m/sec. As air temperature is increased, the speed of sound also increases approximately 0.71 m/sec for each degree.

The distance between two adjacent compressions or dilatations in the sound wave is called the wavelength (λ). The wavelength is related to frequency and the speed of sound by the simple ratio:

$$\lambda = \frac{c}{f}.$$

The lower the vibration frequency, the greater the wavelength and vice versa; therefore, low tone sounds are sometimes called long-wave, and sounds with a high tone — short-wave. Wave lengths are measured in meters.

The field covered by vibratory processes is called the sound field, and the area in a homogenous medium in which sound waves are freely propagated without /7
being reflected by a surface is called the free acoustic field. Under natural conditions, free acoustic fields are encountered very infrequently. More frequently, in industrial shops, besides the forward waves diverging from the sound source, we encounter waves which are reflected from the floor, walls, ceiling and other surfaces. The greater the intensity of the reflected waves, the more the shop "reverberates." The reverberation of the shop is evaluated by the reverberation time — the time it takes for sound pressure after instantaneous shut-off of the sound source to decrease a thousand times in comparison with the original steady value.

As the propagation of sound waves is related to the transfer of vibrational energy in space, the amount of sound energy passing through an area of 1 m^2 perpendicular to the direction of sound wave propagation is called the intensity or force of sound (I). The unit of measurement of the intensity of sound is watts per square meter (W/m^2).

Sound pressure or the intensity of sound are characteristics of a sound field at a certain point of space. Total sound energy emitted by the source to the surrounding space per unit of time is called acoustic power. Acoustic power is measured in watts and does not depend on the location of the measurement point, the direction of radiation or conditions of sound wave propagation.

It is known that the ability of the auditory analysor to register the wide range of sound pressures produced is due to the fact that, not only is the difference discerned, but the rate of changes in absolute values (stepped character of perception). It has been established that each succeeding step of perception differs 12.4% from the preceding one.

The minimum value of sound energy which is perceived by the human ear as a sound is called the auditory threshold and is 10^{-12} W/m^2 (for a tone of 1000 Hz); the sound pressure corresponding to this is $2 \cdot 10^{-5}$ n/m^2, or $2.04 \cdot 10^{-1}$ at. The upper limit at which noise perceived by a human ear causes a sick feeling corresponds to a sonic force of 10^2 W/m^2 or $6.44 \cdot 10^{-4}$ at.

In order to measure acoustic phenomena, it would be necessary to adopt a special measurement unit for the intensity of sound as well as for its energy. As is known, according to the Weber-Fechner law there is an approximate logarithmic dependence between stimulus and auditory sensation, so that there is a very large area between the threshold of audibility and the threshold of feeling. With the aid of ordinary pressure measurements (n/m^2) or with the measurement of intensity (W/m^2), the auditory range would be expressed in unusually large numbers. Therefore, instead of a scale of absolute sound pressure and sound intensity, a relative /8 logarithmic scale is usually used which is also most objective for the corresponding physiological characteristics of perception. The use of this scale sharply reduces the range of measured values. According to it, each succeeding step is 10 times greater than the preceding, which is arbitrarily taken as 1 bel (1 B). Thus, if the intensity of one sound is 100 times greater than another, it is considered that the level of force of the first sound is 2 bels greater than the second; if it is 1000 times, then it is 3 bels more, etc. A threshold intensity of sound with a frequency of 1000 Hz - $I_0 = 10^{-12}$W/m^2 is taken as the arbitrary level. The values measured in this way are called levels (L) of noise or sound intensity.

The common logarithm of the ratio of two intensities of sound I and I_0 is called the level of one of them in relation to the other, i.e., the level of intensity to sound

$$L = \lg \frac{I}{I_0} .$$

Thus, the level of the loudest intensity of sounds encountered in industry with an intensity of 100 W/m² will be: $L = \lg \frac{I}{I_0} = \lg \frac{10^2}{10^{-12}} = \lg 10^{14} = 14$ B,

and the level of the threshold sound (I_0):

$$L = \lg \frac{I_0}{I_0} = \lg \frac{10^{-12}}{10^{-12}} = \lg 10^0 = 0 \text{ B}.$$

In acoustics a smaller unit (0.1 bel) is used, called a decibel (dB). The level of intensity of sound, expressed in decibels, is determined by the formula:

$$L = 10 \lg \frac{I}{I_0} \text{ dB}.$$

As the force of sound is proportional to the square of the sound pressure, L can be expressed by means of the sound pressure:

$$L = 10 \lg \frac{I}{I_0} = 10 \lg \frac{p^2}{p_0^2} = 20 \lg \frac{P}{P_0} \text{ dB},$$

where $P_0 = 2 \cdot 10^{-5}$ n/m².

The decibel scale has the advantage that the entire huge range of intensities — from barely audible to extremely loud — is expressed in numbers from 0 to 140 dB, making it possible to use small numbers in evaluating the level of noises.

As instruments of directly measuring the intensity of sound have not yet been created, the energy state of a sound field at a certain point is usually characterized by sound pressure. Sound pressure is determined in measurements using a standard sound meter; it is the root mean square at a given time of measurement T:

$$P_{rms} = \sqrt{\frac{1}{T_0} \int^{T} |P(t)|^2 dt}.$$

This value, expressed in decibels over the threshold of audibility, is called the level of noise intensity.

Besides the root mean square value, characteristics of noise can also be designated by the mean or peak value of sound pressure. However, they are not widely used in measuring noise, as they are not directly connected to an expression of power. Mean and peak values of noise are less stable factors than the root mean square value, which can be explained by the dependence of these ratings on phase relations of the frequency components of noise.

An exceptionally important characteristic of noise is the density of power distribution through the frequency spectrum or the density of the energy spectrum of noise. Noise can roughly be considered as composed of an infinitely large number of sinusoidal vibrations, whose frequencies lie in the noise band, but whose phases are completely random. The noise function is a result of pulsations of these sinusoidal vibrations. Harmonic analysis must not be directly applied to noise functions, as they are not representable in the form of precise functional time dependences. However, the realization of the noise function, limited to the time interval T, can be expanded. As a result of this operation, actual noise is replaced by a "periodic" function at interval T. The legitimacy of such a concept is determined by the purposes of a specific study or calculation and is used in many practical cases.

As the amplitudes which comprise the noise spectrum are infinitesimal, the concept of spectral power density $S(\omega)$ is used as the final measure, which can be expressed as

$$S(\omega) = \frac{dN}{d\omega},$$

where S (large) is the power per unit of angular frequency:

$$\omega = 2\pi f.$$

In practice, the noise spectrum can be obtained with the help of spectral /10 analyzers, in which the spectral components are expressed by the power per bandwidth of analyzer filters. The time interval during which the noise function is being evaluated by spectral density is determined by band-pass analyzer filters, and is called the time of analysis. The noise spectrum is divided by width into narrow-band and wide-band. Noise with a continuous energy spectrum is called narrow-band, when the energy spectrum of the process is basically concentrated in a relatively narrow frequency band around a certain fixed frequency f, or wide-band, if these conditions are not met.


a b c

Figure 1. Noise spectra: a - line or discontinuous; b - continuous; c - mixed spectrum.

Continuous and discontinuous noise are distinguished by the intervals between separate components (Figure 1). When separate frequency components follow uninterruptedly one after the other, with infinitesimal intervals, such noise is called continuous. When individual components are separated from each other by frequency intervals, the noise is called discontinuous or line. Mixed noise is that in which individual discontinuous components are superimposed on a continuous spectrum background. Noise whose spectral density is uniform through the whole range of frequencies is called white noise (analogous to white light, which has a continuous and approximately uniform spectrum in this visible part). White noise is characterized by the fact that its "values" at any two times (even arbitrarily close) are not correleated. We must note that this definition of white noise relates only to the spectral pattern of a random process and the question of laws of distribution remains completely open.

White noise is an idealization, never realized in actual conditions, as, first, sufficiently close values of a random function are practically always dependent, and secondly, real processes have finite power, and for white noise full power of the process is infinite.

The graphic representation of frequency-amplitude characteristics of noise is called a spectrogram, in which geometric mean frequencies in Hertz are plotted along the abscissa in logarithmic scale, and corresponding levels of sound pressure in decibels — along the ordinate axis. /11

Based on the character of the spectrum, noises are also divided into tonal and atonal.

In the first category the fundamental tone is fully expressed. Such noises are characteristic of the majority of equipment with rotating parts, especially at high speeds (carriers, pneumatic machines, etc.).

The second group of noises — atonal — includes components which are not connected with the working parts of machines, but controlled by vibration of its components, excited by recurrent impacts, in other words — by a number of damped waves.

Each one corresponds to the natural frequency of a certain vibrating part. Most machine noise includes tonal and atonal components, but either can have an energy maximum.

If in the composition of the noise, sound intensities with vibration frequencies below 300 - 400 Hz predominate, this is called low-frequency noise. If the sound intensities in the area of vibrations between 400 and 1000 Hz predominate, it is called middle-frequency noise; if the highest levels in the spectrum are above a frequency of 1000 Hz, it is high-frequency noise.

In hygiene practice, noise has been subdivided into stable (stationary) and discontinuous, or pulsed noise, belonging to the class of unstable noises. Pulsed noise develops in industrial situations as a result of infrequent impacts or the interrupted course of a technological process and differs from stable noise in innumerable parameters.

Evaluating and measuring such noises present certain difficulties. On the one hand there is a lack of suitable measuring instruments, and on the other — the necessity of selecting from the aggregate of parameters only the most essential.

Stable noise is characterized by a constant level of sound pressure; fluctuations, including 2 - 3 dB changes in level, are permissible. Rotation and reciprocating machines usually cause this kind of noise.

Pulsed noise is primarily characterized by a changing level of sound pressure in time; these changes proceed rapidly, over 5 dB per second. In determining the physical parameters of stable noise, it is sufficient to consider the level of intensity or sound pressure as well as spectral characteristics, but with pulsed noise it is also important to consider a number of additional parameters which have a definite effect on the organism of the workers.

As has already been noted, the primary characteristic of most noise processes is the uncertainty of instantaneous values of sound pressure, amplitude, and /12 frequency in the sequence of noise emissions, both in the considered and subsequent moments of time. For full characteristics of the noise process, unlimited time is necessary; however, in practice, time is reduced to a minimum, adequate to obtain the necessary concept of the noise function as a whole.

On the basis of a segment of the noise function in measurement time interval, called the realization of a random process, an idea is usually formed about the entire noise process as a whole. Statistical characteristics of noise, calculated according to the realization, can be considered reliable, i.e., pertaining to the entire noise process as a whole, only if the random noise is stationary. Stationarity means continuity, statistical uniformity of noise in time. In practice, in order to consider the noise function stationary, it is enough that the external conditions producing the noise remain constant throughout the entire time, relating to the measured characteristics. Continuity (invariance) of parameters of the noise process distribution when the interval in which the sample is produced is shifted along the time axis, is subjected to the stationarity hypothesis. Stationary noise is primarily normal (Gaussian), in which instantaneous values, measured at random moments of time, are distributed according to a normal law.

Unlike this measurement, the evaluation of unstable noises also presents certain difficulties. On the one hand, there is a lack of suitable measuring instruments, and on the other — the necessity of choosing from the aggregate of parameters only the most essential.

Striving to extend the range of application of averaging to unstable noises, G. A. Suvorov and A. M. Likhnitskiy (1968) recommend using the concept "instantaneous power" [N(t)], which, characterizing the process as a whole, expresses not one value, but many obtained for each moment of time individually.

Each value of instantaneous power is calculated by averaging in a given interval of time Δt_0. The sequence of discontinuous values is preferably replaced by a continuous function. Instantaneous power is there calculated on the basis of the initial process by sliding integration according to the formula: /13

$$N(t) = \frac{1}{\Delta t_0} \int_{t-\frac{\Delta t_0}{2}}^{t+\frac{\Delta t_0}{2}} |P(t)|^2 \, dt.$$

In the analysis process, the time interval (Δt_0), within which averaging takes place, is intermingled with instantaneous time along the initial noise process. As a result, the function of instantaneous power is formed, describing a continuous curve where each value represents power which corresponds to the instantaneous moment of time and is determined in the interval (Δt_0).

In practice, the instantaneous value of the root mean square value of sound pressure is used to judge the instantaneous power in measurements. This is calculated from the instantaneous power of the acoustic process:

$$P_{rms}(t) = \sqrt{N(t)}.$$

The function of the instantaneous root mean square value of sound pressure must be considered as a statistical envelope of the noise process. The relation between the initial noise process and the envelope is given in Figure 2, for a case with exponential pulsed noise.

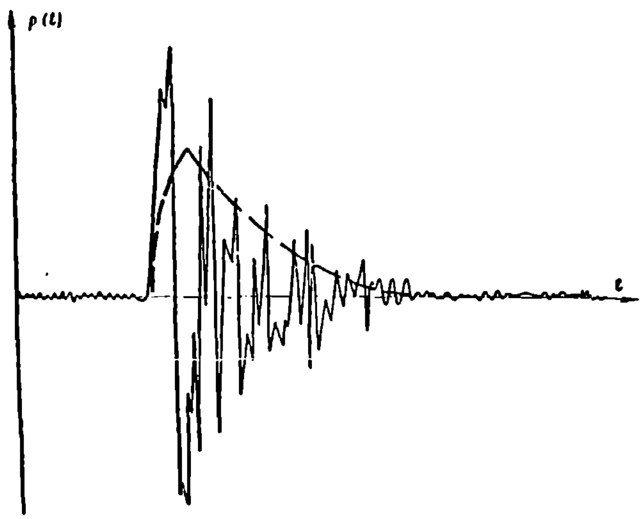


Figure 2. Exponential impulse of noise and its envelope. Vertically - sound pressure; horizontally - elapsed time.

The evenness of the envelope depends on the value of the integration interval (Δt_0). Too great an integration can conceal from study steep drops of sound pressure which largely determine the biological effect of unstable noise. On the other hand, a very small integration time can complicate the noise process picture.

Niese (1963) suggested a constant of integration for pulsed noise Δt_0 — 23 msec. True, the author does equate pulsed noises with stable noises in subjectively evaluating their loudness, which, of course, still says nothing about the adequacy of their biological effect.

G. A. Suvorov, on the basis of his own psychophysical and physiological studies on the effect on the human organism of dynamic parameters of pulsed noise, suggests for the averaging interval a value of 10 msec, as most adequate for the time characteristics of perception and the effect of noise for man.

We must note that, for a standard sound meter, the time constant has been established at 200 or 500 msec.

Instantaneous values of noise can be measured and the function of the instantaneous root mean square value can be registered by using automatic recorders. Because of its speed of response, a 2305 "Bruel and Kjer" recorder in an RMS cycle is best suited to record the envelope of complex signals. Equipped with a logarithmic potentiometer (50 dB), the recorder reproduces a jump in levels of 20 dB in 20 msec. Inertia of the stylus in this case serves the function of sliding integration (summation). An arbitrary constant of integration can be obtained using an IChM cathode ray oscillograph, equipped with a square-law detector, and an integrating circuit, as the recording instrument. /14

A simplified description of unstable noise can be obtained if the enveloping noise is periodic. Then the envelope is described by the ratio:

$$P_{rms}(t) = P_{rms}(t + jT),$$

where $j = 1, 2, 3...t$; T — the smallest value satisfying the equation, is a period and represents the time interval between the moment one pulse appears and the moment the next pulse appears. If the behavior of a periodic signal is known per period, then its next one can be "predicted," i.e., one period of noise of a periodic envelope is completely described by the values for one period. As within interval T, energy is not equal to 0 and is basically concentrated in the interval $t_k < T$, the oscillation of the noise envelope in this interval t_k can be considered to be pulsed. /15

The basic parameters of pulsed oscillations are the slope of the edge and the spacing of the impulses.

Slope of the edge of the impulse (S_F) is equal to the ratio of the amplitude of the pulse to the length of the front:

$$S_F = \frac{P_{rms\ max}}{t_F}.$$

A lateral side of a pulse is called its edge. Leading and trailing edges differ. The length of the leading edge determines the rise time of the impulse. The length of the trailing edge determines its decay time.

Off-duty factor. By off-duty factor is meant the ratio of the repetition period T to the length of the pulse. The reciprocal of the off-duty factor is called the duty factor (K). It is equal to the ratio of the length of the pulse to its repetition period:

$$K = \frac{t_k}{T}.$$

Thus, unstable noise, which is characterized by a definite repetition period, form, and ultimate energy is called pulsed periodic noise. When it is being produced, pulsed noise is accompanied by a constant level of "background noise" ("quasi" — an almost constant level, the value of which is especially important in cases when it is comparable with the amplitude of the pulse).

Pulses of similar shape in one period can be described analytically, i.e., in the form of a combination of simple functions, or by means of matching special functions. Analytical representation of the envelope of the acoustic process by approximate (but not exactly coinciding with them) functions from a mathematical point of view is the task of approximation.

We most often encounter an envelope of pulses in the form of functions, exponentially decreasing, exponentially increasing and decaying, square and trapezoidal pulses (Figure 3). Although pulsed periodic noises are not stationary, they can be considered as structurally uniform. A general equivalent evaluation can be given for structurally uniform noise in the form of power N of the acoustic /16
process. Power is calculated on the basis of the realization of this process, and when measurement time is increased it approaches certain limits.

In contrast to the instantaneous power of structurally uniform noises, G. A. Suvorov and A. M. Likhnitskiy suggest that the limiting value of the average instantaneous power with unlimited increase of averaging time (τ) be called average power.

For periodic pulsed noise, the value of the average power is equal to the average value of instantaneous power for one period, regardless of the position of the time interval, equal to the period:

$$\langle N\rangle = \frac{1}{T}\int_{-\frac{T}{2}}^{+\frac{T}{2}} |P(t)|^2\,dt.$$

It follows from this formula that average power is determined as the energy per period, multiplied by the number of periods per second. This can be used to calculate average power on the basis of an analytical recording of periodic pulses.

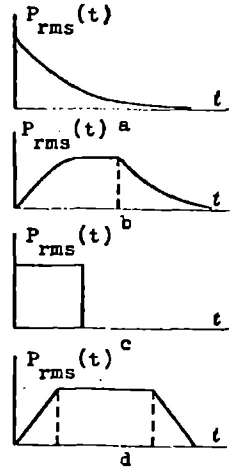


Figure 3. Often encountered shapes of pulses: a - exponentially decaying; b - exponentially rising and decaying; c - rectangular; d - trapezoidal.

Average power is the general energy characteristic of both pulsed and stable noise. By comparing the average power of pulsed noise with the power of stable noise, the effect of pulsed noise on the organism can also be determined and its most essential parameters can be distinguished. For this, pulsed and stable noises of equal average power and the same spectral composition must be compared.

Under industrial conditions, the average power of structurally uniform noise can be measured with a random noise volt meter with a large averaging time $\tau \gg T$. For this purpose, we can recommend the use of a 2417 "Bruel and Kjer" instrument with an averaging time from 0.3 to 100 seconds. Obtaining the general spectral characteristics of unstable noise at the operator's position is of interest, as /17
it makes it possible to compare the results of analyzing the spectrum of pulsed noise with stable noise. The general spectrum of noise is an average characteristic of the spectrum of pulsed noise with a long analysis time, including stationary and pulsed parts of noise. Ye. Ts. Andreyeva-Galanina, G. A. Suvorov and A. M. Likhnitskiy (1968) suggest these characteristics of the time-averaged spectrum be produced on 2112 three-octave spectrum analyzer, together with a 2305 automatic recorder.

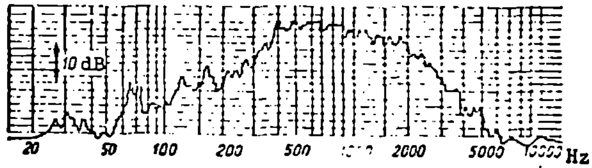


Figure 4. Time-averaged spectrum of noise at the worker's position in the stamping industry in three-octave bands, produced on a type 2142 analyzer: Horizontally - frequency (in Hz); vertically - intensity of noise (in dB).

To produce a general power spectrum of pulsed noise, it is necessary to use a large enough integration time (including pulses and pauses) or average a large number of measured brief spectral distributions. In this power spectrum, averaged over a long period of time, unlike instantaneous power, all changes will be completely evened out, commensurate with the length of the noise period. The results of measuring the power spectrum of noise, averaged for a long period of time, are given in Figure 4.

Measuring and Standardizing Noise in Industry

Measurements of noise in industry to evaluate and compare its levels and spectra with the requirements of health laws must be made at operators' positions at a height of 1.5 m from the floor; in shops with an equal distribution of noisy equipment at two-three points along the long axis of the room — at one-third the distance from the side walls; in shops with a concentrated arrangement of noisy units — at a distance of 1 m from the unit on the side of the sound source. More detailed information on measuring machine noise at the present time is discussed in the monographs of Yu. M. Il'yashchuk (1964) and I. K. Razumov (1964). /18

Noise is measured with sound meters and frequency analyzers with a constant, relatively wide transmission band. We must note that it is impossible to track all changes in intensity with a sound meter if it changes rapidly. For this, we usually have recourse to automatic level recorders, which consist of a sound meter indicator, which records all instantaneous values of the intensity level.

Frequency composition at the sound source is also directly determined by using a sound meter (Sh-3M LIOT, SH-3 IRPA, etc.), which, in this case, is a sound amplifier with an outlet to the analyzer. Analyzers can be octave, half-octave, three-octave or narrow-band filters. An octave is a frequency interval in which the upper frequency is two times greater than the lower. The entire range of audible sounds is nine octaves. Of greatest practical importance are the eight octaves from 62 to 10,000 Hz. Therefore, to reduce the graphs, frequencies above 10,000 Hz are not considered.

In a number of cases when analyzing complex noise processes in laboratory conditions, preliminary recording of noise is resorted to with the help of a tape recorder. In this case, it is necessary that distortions inserted by the recording do not exceed permissible values. The level of noise is measured by a sound meter which serves as a preliminary amplifier. A list of characteristics of valid sound instruments are given in Tables 8 — 12.

"Temporary Health Standards and Regulations on Noise Limitation in Industry" No. 205-56, the first such standards in world practice, were introduced in the Soviet Union in 1956. Norms regulated stable noises affecting the workers through the entire working day; standardized parameters were the level of sound pressure of noise and its frequency spectrum. All noises, as has already been indicated, depending on frequency composition, are subdivided into three classes; low-frequency, middle-frequency and high-frequency (Table 1).

The maximum permissible level of sound pressure has been established for each of these classes.

The main document regulating the characteristics of noise is a graph (Figure 5), which also determines the intermediate values of permissible noise levels within the classes. The diagonal lines on the graph indicate boundaries of basic and intermediate classes. These lines indicate the permissible levels of total sound pressure of noise, the frequency spectrum of which does not extend beyond the corresponding curve, i.e., in essence, the lines are maximum frequency spectra of noises with varying levels of sound pressure.

TABLE 1

PERMISSIBLE LEVELS OF NOISE IN INDUSTRY FOR NOISES OF VARIOUS CLASSES

Class	Noise Characteristics	Permissible Level, dB
1	Low-frequency noises (noises of quiet-running, non-percussive units; noises heard through soundproofing barrier-walls, ceilings, coverings). The highest levels in the spectrum are below a frequency of 350 Hz, above which the levels are reduced (not less than 5 dB per octave)	90 - 100
2	Middle-frequency noises (noises of most machines, machine tools, non-percussive units). The highest levels in the spectrum are below 800 Hz, above which the levels are reduced (not less than 5 dB per octave)	85 - 90
3	High-frequency noises (ringing, hissing and whistling noises, characteristic of percussive units, air and gas flows, and high-speed units), highest levels in the spectrum are over 800 Hz.	75 - 85

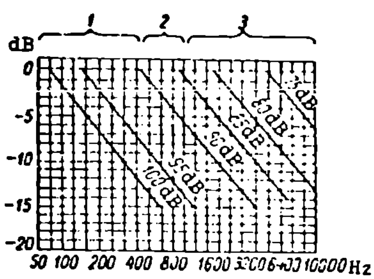


Figure 5. Maximum permissible level of noise intensity with various frequency spectra (VSN205-56): 1 - low-frequency; 2 - middle frequency; 3 - high-frequency noises; horizontally - frequency; vertically - relative levels of sound pressure in spectrum bands.

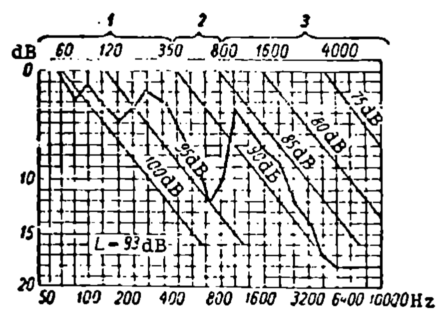


Figure 6. Spectrum of noise, plotted in relative levels of sound pressure L = 87 dB, L_{act} = 93; 6 dB over the norm: Horizontally - frequency; vertically - relative level of noise in bands. 1, 2, 3 - classes of noises.

The level of sound pressure permissible for a given noise is read on one of the diagonal straight lines of the norm graph — the first, counting from left to right, beyond which the measured spectrum does not extend. At individual points, the spectrum graph can extend no more than 3 dB beyond the norm line. If the envelope of the spectrum does not coincide with any of the diagonal lines of the pattern, a line is drawn parallel to the existing lines, touching the decaying part of the spectrum. Then the permissible level is determined by interpolation.

Noise is permissible if the readings on the sound meter are less than the level of sound pressure indicated on the next spectrum envelope. Otherwise, the difference between actual levels, measured by the sound meter, and permissible levels indicates the excess of norm in decibels.

Example 1. The general level of noise is 93 dB. The noise spectrum, measured by an ASh-2 LIOT three-octave filter, is given in Table 2.

TABLE 2

NOISE SPECTRUM

Pass Bands												
40	50	64	80	100	125	160	200	250	320	400	500	[illegible]
11	11	11	14	13	14	16	15	13	14	16	13	24
We assume the maximum value is 0												
0	0	0	3	2	3	5	4	2	3	5	8	13

Continuation

Pass Bands											
800	1000	1250	1600	2000	2500	3200	4000	5000	6400	8000	10 000
21	15	17	19	20	23	25	28	30	30	30	30
We assume the maximum value is 0											
10	4	6	8	9	12	14	17	19	19	19	19

According to the data in Table 2, on the form (scale identical with the norm graph) we plot the measured values of the noise levels in bands down from 0 dB (Figure 6).

In our example, the noise standard is 87 dB; the general level of noise is 93 dB, which exceeds the norm by 6 dB.

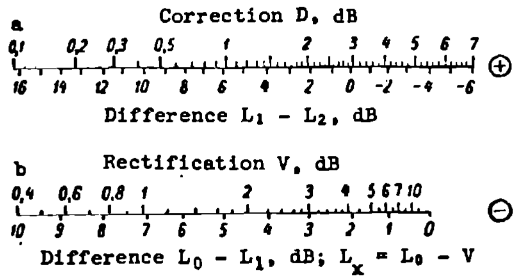


Figure 7. Nomograms for decibel operations: a - with energy summation of levels; b - with energy deduction of levels.

Absolute levels in individual bands were determined by the nomographic method. Figure 7 gives a nomogram for sound pressure level summations. /21

Relative levels of sound are summarized as follows. The difference between levels L_1 and L_2, using the nomogram, determines the value — D, which is added to the first level L_1, as a result of which the summary level of noise of two transmission bands is obtained. Considering this level as the level of the average equivalent band, it is summarized with the level of noise of the third band, a level of noise of the band equivalent to the first three is found, and so forth, until the general level of noise is determined for all analyzer bands. To reduce the probability of random calculations errors, it is recommended that initial data be recorded and the results computed in the form of a table.

Example 2. Noise, measured by a three-octave analyzer, has a level of 112 dB. The spectrum is given in relative levels (Figure 8).

The relative spectrum measured by a three-octave analyzer must be converted to an "absolute" one, i.e.,levels of sound pressure relative to $2 \cdot 10^{-5}$ N/m^2 must be calculated in all pass bands of the analyzer.

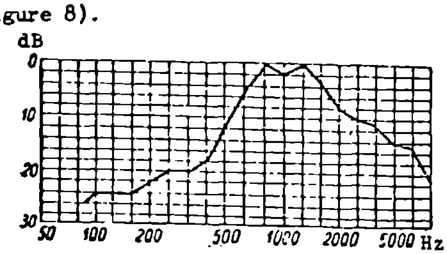


Figure 8. Noise spectrum, plotted in relative levels. Horizontally - frequency; vertically - level in band L_p.

TABLE 3

RECORD OF COMPUTATION RESULTS*

f, Hz	$L_{sum} + D$	L_1	$L_{sum} - L_1$	D
800	—	0	—	—
1250	0[1] +3.0 3	0	0	3
1000	+1,0 4	—3	6	1
1600	+0,63 4,63	—4	8	0,63
640	0,5 5,13	—5	9,63	0,5
2000	0,23 5,36	—8	13,13	0,23
2500	0,08 5,44	—10	15,36	0,08
	$L_{gen} = 5.44$			$\Sigma D = 5.44$

[1] In the second line, level L_1 is assumed to be the first L_{sum}.

*Translator's Note: Commas represent decimal points.

All the results must be entered in Table 3, where Column 1 lists the average frequencies (f) of transmission bands of the analyzer. Levels (L_2), measured in the pass bands, are recorded in Column 3; for convenience in calculating it is recommended they be arranged in decreasing order. Levels 10 - 12 dB below the maximum cannot be included in the table, as they have practically no effect on the general level of noise. In Column 2, we record level L_1 before level L_2. We enter the difference of $L_1 - L_2 = 0 - 0 = 0$ dB in Column 4. We determine correction D = 3 dB, corresponding to this difference, by the above nomogram. This correction is recorded in Column 5, as well as in Column 1 under level L_1, with which it is summarized. The sum which is found (L_{sum}) = 3 dB, is the level of noise equivalent to bands with levels L_1 and L_2. Then we calculate the difference $L_{sum} - L_3$ (Column 4), again determine the correction (Column 5) and summarize (Column 2), which gives the level of noise in three pass bands, and so forth. The last value $L_{sum} = 5.44$ is the general level of noise L_{gen} of all bands in a corresponding scale. Level L_1 and all corrections D are summarized to prove the calculation. The sum obtained in this way is compared with value L_{gen}.

/22 /23

The final result shows by how many decibels the general level of the sum of signals in the pass bands of the analyzer exceeds the level of the most intensive band. Considering the discarded components, the corrections found can be rounded off to 6 dB.

For calculating the absolute level of sound pressure in bands with medium frequencies f = 800 Hz and f = 1250 Hz corresponding to the peak of the spectrogram, the correction: $L - \Sigma D = 112 - 6 = 106$ dB must be deducted from the sound meter readings. Arranging peaks with reference to the spectrum on the horizontal corresponding to the level of 106 dB, we obtain the frequency spectrum plotted on absolute levels, i.e., the graph of the entire spectrum is shifted vertically along the scale of levels as many decibels as are necessary so that the level of the spectrum peak is less than the total noise level by the amount of the calculated correction (Figure 9).

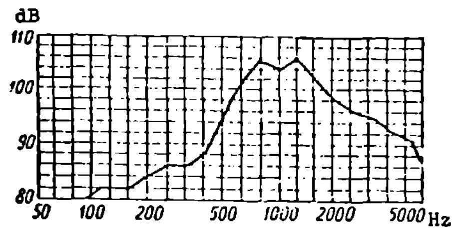


Figure 9. Frequency spectrum, plotted at absolute levels: horizontally - frequency; vertically - level of sound pressure relative to $P = 2 \cdot 10^{-5}$ N/m^2.

To convert the levels of sound from a 1/3-octave band to an octave, it is necessary to sum the levels of sound pressures, using the nomogram and the method given above. From the summary level L which is obtained, ten logarithms of the number of averaged levels must be deducted: /24

$$L_{av} = L_{gen} - 10 \lg n \text{ dB},$$

where n is the number of averaged levels.

Example 3. The level of noise, measured by a sound meter with a 1/3-octave filter in the analyzer, is, respectively: 50 Hz - 93 dB; 62 Hz - 91 dB; 80 Hz - 84 dB. The average level of noise in the octave band with a geometric mean frequency of 62 Hz must be determined (Table 4).

At first the levels are summarized, allowing for the logarithm $3 = 0.48 \cdot L_{av} = L_{sum} - 10 \lg n = 95.26 - 10 \lg 3 = 90.46$ dB, i.e., we obtain the level of noise in the first octave.

TABLE 4

SUMMARY OF NOISE LEVELS

f	$L_{sum} + D$	L_1	$L_{sum} - L_1$	D
50	—	93	—	—
62	93.0 +1.89	91	2	1.89
80	+3.37	84	10.89	0.37
L_{gen} =	95.26			$\Sigma D = 2.26$

The main advantage of the natural norm, which has not yet lost its value, is the dependence of the permissible level of noise sound pressure on frequency; noise is evaluated by the level of sound pressure, which makes it possible to verify the norms roughly, using only a sound meter without frequency analysis. It is enough to determine whether the noise belongs to one of the frequency classes, which in turn can be done by a norm reference table.

We must note that the basic fault of operative norms is the rather inconvenient means of graphically representing them and the fact that they are primarily based on protecting hearing in the area of sounds necessary for speech communication and unfavorable sensations from the effect of noise, not considering other more important functions for the normal vital activities of the organism.

We must note that, in evaluating the effect of noise or determining standards, in essence only one criterion has until recently been followed — the value of temporary shifts in auditory thresholds after the brief effect of noise. It has been suggested that permanent hearing loss in the future will be approximately this amount. However, this question of the connection between temporary increase /25
in auditory thresholds and the development of persistent hardness of hearing is debatable. Glorig (1958), Glorig, Ward, Mixon (1961) concluded that the shift in the auditory threshold in decibels, developing as a result of eight-hour exposure to noise, is nearly adequate for permanent loss of hearing by the end of ten years. Wheeler (1950) feels that a temporary increase of auditory thresholds and persistent hardness of hearing are identical conditions; only in the second case, recovery of hearing is carried to infinity. T. M. Radzyukevich (1968) also notes a connection between temporary shifts in the auditory threshold and permanent shifts, depending

on time on the job. The author has established a direct relation between permanent thresholds of auditory sensitivity and the logarithm of the length of time on the job.

According to Ya. S. Temkin (1968) the degree and character of temporary reduction of hearing depends primarily on the mobility of stimulating and inhibitory processes in the cerebral cortex. Underlying persistent hardness of hearing is damage to the Corti organ, whose rate of development depends not only on the parameters of the noise, but also on a number of other conditions affecting blood circulation, metabolism, the state of cochlear receptors, reactivity of the organism itself, etc. Kryter (1963, 1965) suggested criteria of risk of hearing damage, which allowed any exposure which, on the average, does not increase the auditory thresholds (measured 2 minutes after exposure to noise was ended) more than 10 dB at a frequency of 1000 Hz, 15 dB at a frequency of 2000 Hz and 20 dB at a frequency of 300 Hz in 15% of persons subjected to the effect of noise (Figure 10). These criteria assume that a permanent increase of auditory thresholds in persons subjected to noise for 10 years will be no greater than the temporary increase of auditory thresholds at the end of the working day in persons working under the same noise conditions.

An attempt has been undertaken by Coles, Garinter, Hodge, Rice (1968) to determine the criterion of risk of hearing damage for high-level pulsed noises with a low pulse formation time. The criteria for pulsed noise proposed by the authors specify the same permissible increases of auditory thresholds as for stable noise, but in 75% of persons subjected to the effect of pulsed noise (Figure 11). The stricter criterion for pulsed noise the authors explain as the great danger it has for the organ of hearing (faster transition from temporary hearing reduction to permanent, higher individual sensitivity to it). Criteria were calculated for pulses with a recurrence frequency of 6 - 30 per minute, as they are the most /26
injurious (Ward, 1962), and therefore they are applicable for any frequency. The authors feel that, although the criteria were based on a study of high-intensity rapid pulses, they, nevertheless, agree with data resulting from a study of laboratory types of pulses with a relatively slow rising front and long duration. Probably these criteria are acceptable for all kinds of pulsed noise, including industrial noise.

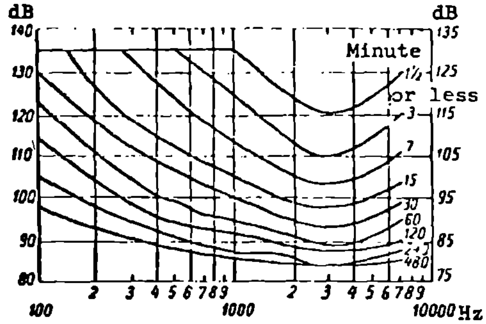


Figure 10. Hearing protection criteria in cases of wide-range noise. Levels of sound pressure, in the octave range and in the range of one-third octave, when it is recommended measures be taken to preserve hearing with various daily effects of noise (after Kryter 1963); horizontally - frequency of central part of the range; vertically at left - level of octave range sound pressure; right first scale - duration; second - level of sound pressure now at one-third octave.

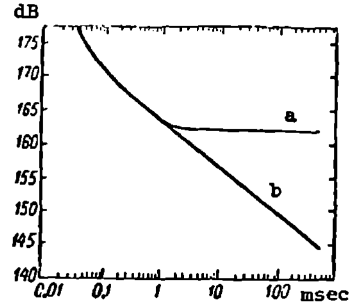


Figure 11. Limit of peak pressure level and duration of pulses (momentary), when no significant hearing reduction is noted: a - duration of pulses in a free acoustic field; b - duration of pulses in reverberation conditions; horizontally - duration; vertically - level of peak pressure.

It is evident that these criteria, based only on data of increased auditory thresholds, cannot satisfy the hygienists, as no attention was given to the importance of protecting the organism as a whole, primarily the central nervous system and a number of other vitally-important systems of the organism. In other words, these criteria do not completely reflect the danger of noise for the organism and are exaggerated. Ye. Ts. Andreyeva-Galanina and G. A. Suvorov (1968) emphasize the necessity of complex evaluation of the effect of pulsed noise on the organism. T. A. Orlova and I. K. Razumov (1968) feel that, to solve the problem of a scientifically-based standardization of noise, it will be necessary to determine the effect of pulsed and discontinuous noise on the reactivity of the central and autonomic nervous system, as well as on the auditory acuity of workers. /27

Workers in a number of professions are subjected to the effect of intense pulsed noise from shooting: gun assemblers, pyrotechnists, shooting instructors, etc. Therefore, it is important to establish the maximum level of noise intensity which will not cause acoustic trauma. This level has been established for stable

noise — 235 - 140 dB (Chaba, 1965; Working group, 1965; Burns, 1965; Kryter et al., 1966). It has also been suggested that for pulsed noise the permissible maximum level can be higher, as the duration of noise pulses is often insignificant, on the order of several msec or less. Gierke (1966), Coles, Rice (1966) feel that with some kinds of pulses the eardrum can be ruptured at a level of 185 dB.

Pfander (1965) indicates that a noise level less than 165 dB is safe if it does not last longer than 3 msec. These data allow longer exposure to noise with levels below 165 dB, on the basis of conservation of equivalent energy. Coles, Garinther, Hodge, Rice (1968) proposed their criteria of maximum thresholds on the basis of data obtained earlier by the authors (Kryter, Garinther, 1965; Coles, Rice, 1966; Hodge, 1965; Hodge, Blackmer, 1966a, b), having studied the effect of pulsed noise from rifle shots on hearing. They suggested a maximum permissible level of 159 dB with a pulse lasting 5 msec and 150 dB for a duration of 100 msec.

In tests on animals, A. I. Aleksandrov and his associates (1963) showed that, if the duration of the pulses is relatively long (0.99 - 0.96 seconds), the level of intensity causing acoustic trauma is 140 - 150 dB. At the same time, P. S. Kublanova and I. V. Pomerantseva (1967) showed under industrial conditions that assembly workers, subjected to the effect of powerful pulsed noise (level above /28
140 dB, duration of pulses 5 msec), do not suffer acoustic trauma, although a decrease is noted in their auditory sensitivity.

A number of foreign authors (Spith, Trittipoe, 1958; Ward, Glorig, Klar, 1958, 1959; Hardy, 1956; Kryter, 1960) in evaluating the effect of discontinuous as well as pulsed noises, use the "rule of equal energy" as a basis, which implies that equal amounts of acoustic energy reaching the ear are equally harmful, regardless of the fact that this energy is distributed in time under conditions where the intensity of this energy exceeds 85 dB. Evidently this rule does not take into consideration many additional aspects of discontinuous noise. Thus, the research of Rol (1965) suggests that this rule is not suitable for pulses with a periodicity of less than 0.5 seconds and that shorter pulses cause greater shifts in the auditory threshold. Ward (1962), Selters (1963) concluded that the shift of the auditory threshold, caused by the effect of pulsed noise, with pulses lasting up to 9 seconds, depends comparatively little on the interval between pulses, and that in this case the number of pulses is more important than the time of exposure.

Cohen (1963) feels that this rule supports an extremely conservative concept of the effect of short noise effects. G. A. Suvorov (1968) considers this rule inadequate for evaluating pulsed noise, especially as its physiological basis is very debatable.

At the present time the USSR State Committee on Construction is suggesting new standards for restricting industrial noise in newly begun and remodeled plants (SN245-63). They correspond to the recommendations of the Engineering Committee on Acoustics of the International Organization on Standardization (ISO TK-43), and establish maximum permissible levels of sound pressure in octave bands of the noise spectrum (Table 5). Noise is considered permissible if measured levels of sound pressure in all octave bands of the spectrum of this noise are below the values indicated by the standard curve. The index of the maximum spectrum was taken as the permissible sound pressure in the octave band with a geometric mean frequency of 1000 Hz. The standard of the sound pressure level, established for any octave band of the spectrum, does not depend on how the other components change in the noise spectrum. Because tonal and pulsed noises are more unfavorable and have a more fatiguing effect than steady noises with continuous spectra, a correction of 5 dB is specified for them. Tonal noise is that whose 1/3-octave spectrum has peaks with levels which exceed those in adjacent bands by 10 dB or more. Pulsed noise results from percussion, perceived as distant impacts, often following one /30
after the other. In testing noise standards, levels of sound pressure and frequency spectra of pulse noises must be measured by any ordinary sound meter and frequency analyzer. The norms specify correction for the length of the noise. If the length of time of the effect is less than four hours in succession, the maximum noise spectra can be increased as the noise duration is shortened.

Unlike norms No. 205-56, the "new" norms do not consider such important noise characteristics as its general sound pressure, since there is a basis for suggesting that the level of loudness (noisiness) basically depends on the level of sound pressure of this noise. A. P. Pronin (1965) shows that if criterion 85 is taken for the norm, no component must exceed it — 85 background. However, the remaining components of the spectrum of complex noise, individually not exceeding criteria 85, in total can greatly exceed it. This excess can only be taken into consideration with the help of those noise characteristics absent from the norms for the general level of sound pressure. On this basis, the maximum permissible noise levels

TABLE 5

MAXIMUM PERMISSIBLE LEVELS OF SOUND PRESSURE IN OCTAVE BANDS OF NOISE WITH A CONTINUOUS SPECTRUM EFFECTIVE FOR FOUR HOURS IN SUCCESSION

	Geometric Mean Frequency of Octave Bands, Hz							
	63	125	250	500	1000	2000	4000	8000
	Sound Pressure Levels, dB							
1. Noise from outside heard in rooms located within industrial plants:								
a. design bureaus, offices of computers and computer programmers, laboratory rooms for analyzing experimental data and laboratories without their own sources of noise	71	61	54	49	45	42	40	38
b. management offices, and health centers	79	70	63	58	55	52	50	49
2. Noises developing within rooms and penetrating rooms located within industrial plants:								
a. electronic computer rooms and precision assembly areas	79	70	63	58	55	52	50	49
b. laboratory rooms, observation and remote control rooms	94	87	82	78	75	73	71	70
c. work sites in industrial plants and in the area of industrial plants and factories	According to the special standards approved by the USSR Ministry of Public Health							
3. On the outside, at a distance of 2 m from the protective enclosures of dwellings and public buildings, located:								
a. in residential areas:								
in the daytime (8 - 23 hrs)	75	65	58	53	50	47	45	43
in the nighttime (23 - 8 hrs)	67	57	49	44	40	37	35	33
b. in hospital zones:								
in the daytime (8 - 23 hrs)	79	70	63	58	55	52	50	49
in the nighttime (23 - 8 hrs)	71	61	54	49	45	42	40	38

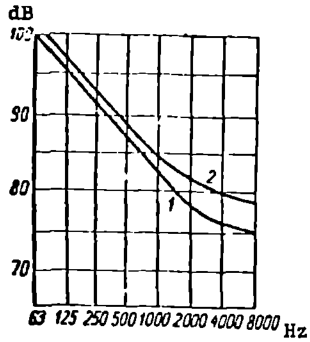


Figure 12. Graph of norms for restricting industrial noise: 1 - norms No. 205-45; 2 - ISO-TK-43 recommendations; horizontally - mean geometrical frequency in octave bands; vertically - level of sound pressure.

suggested by ISO-TK-43 for work sites in factory buildings lack verification based on the effect of noise on the organism.

We must note that back in 1938 G. L. Navyazhskiy suggested specifying noise with an intensity level of 70 dB as permissible for ordinary, and 65 dB for especially high-frequency, noises. I. I. Slavin in 1955, in discussing health norms suggested norm curves for tonal noises or for those with continuous spectra by averaging norm lines of a norm chart (Figure 12).

According to the data of E. P. Orlovska (1962b), the maximum permissible intensity of noise at frequencies of 1000 - 1600 Hz is 70 dB. The limit of the harmless effect of stable noise, according to the data of A. A. Arkal'evskiy (1963), at 95, 85, 75 and 65 dB can correspond to spectrum frequencies of 200, 600, 1250, and 4000 Hz. S. V. Alekseyev and G. A. Suvorov (1963) have established that stable wide-band noise with a level of 70 dB in the range from 30 to 12,000 Hz does not cause pronounced shifts in a number of physiological functions of the organism. S. V. Alekseyev (1968 a, b) noted no reliable changes in the functional state of the organism under the effect of noise with an intensity of 75, 70 and 65 dB with octave bands respectively of 300 - 600, 600 - 1200, and 1200 - 2400 Hz. T. A. Orlova (1965) recommends the ISO-TK-43 No. 75 curve as a standard.

Now researchers are faced with the problem of once and for all finding out what levels of noise in individual octave bands do not cause unfavorable shifts in the functional state of the human organism and can be accepted as maximum standards. Therefore, approving a final criterion, in the form suggested by ISO-TK-43 (curve 80 or 75), will require further thorough study and verification under both experimental and industrial conditions.

TABLE 6 /31

PERMISSIBLE LEVELS OF SOUND PRESSURE AND LEVELS OF SOUND AT WORK SITES IN FACTORIES AND IN THE AREA OF INDUSTRIAL PLANTS

Name of Room or Area	Mean Geometric Frequency of Octave Bands, Hz								Level of Sound, dB A
	63	125	250	500	1000	2000	4000	8000	
	Level of Sound Pressure, dB								
1. Rooms for mental work without sources of noise (studies, design bureaus, computer and programmer rooms, laboratory rooms for theoretical work and analyzing experimental data, health centers, and other such places	71	61	54	49	45	42	40	38	50
2. Places requiring clear verbal communication and telephoning (dispatch points, control desks, telephone and radio-telephone signal centers, observation rooms	75	66	58	54	50	47	45	44	55
3. Offices with sources of noise (typewriters, manual calculating machines, telegraph equipment, switchboards), as well as precision assembly and snop administration rooms, plant dining rooms, and other such places	79	70	63	58	55	52	50	49	60
4. Areas with consoles, observation rooms and remote control units not requiring verbal communication	83	74	68	63	60	57	55	54	65
5. Laboratory rooms with sources of noise, as well as places with noisy computers (digital printers, tabulators, magnetic drums, etc.)	91	83	77	73	70	68	66	64	75
6. Work sites in factories and in the area of industrial plants	99	92	86	83	80	78	76	74	85
7. Housing areas in an urban region 2m from residential buildings and the edges of parks in city blocks and microregions adjoining industrial plants and their environs /31	63	52	45	39	35	32	30	28	40

Comments:

1. Corrections for length of the effect of noise do not apply to Paragraph 7 at night or to Paragraph 2 during the day or at night.

(Continued)

TABLE 6 (Continued)

PERMISSIBLE LEVELS OF SOUND PRESSURE AND LEVELS OF SOUND AT WORK SITES IN FACTORIES AND IN THF AREA OF INDUSTRIAL PLANTS

2. For plants working only a day shift, add 10 dB to the vulues indicated in Paragraph 7. In arranging plants in a suburb, deduct 5 dB from the values indicated in Paragraph 7 and in an industrial erea — add 5 dB.

3. Consider the levels of noises created in rooms by ventilators, to be 5 dB lower than those indicated in Table 1 or actual levels of noise in these places, if the latter do not exceed normative values according to Table 6.

4. For juveniles, the levels indicated in Paragraph 6, Table late to a four-hour working day.

5. Ministries and departments of the USSR, in order to improve working conditions, are resolving, in conformity with the USSR Ministry of Public Health, to establish in accordance with their standard nomenclature departmental standards on noise levels, not exceeding, however, the maximum permissible levels indicated in Table 6.

TABLE 7

CORRECTIONS TO TABLE 6 FOR OCTAVE LEVELS OF SOUND PRESSURE AND LEVELS OF SOUND

Influencing Factor	Conditions	Corrections in dB or dB A
Character of noise	Wide-band	0
	Tonal, pulsed, measured by standard noise meter	-5
Duration of noise	Total duration during a shift	
	from 4 to 8 hours	0
	from 1 to 4 hours	+6
	from 1/4 to 1 hour	+12
	from 5 to 15 minutes	+18
	less than 5 minutes	+24

Comment:

1. The duration of noise must be substantiated by calculation or subjected to technical documentation.

2. Tonal noise is considered to be that in which a sound of a definite frequency is heard.

3. Pulsed noise is that perceived as impacts following one after the other.

On 30 April 1969, the Ministry of Public Health of the USSR approved No. 785-69 "Health Standards and Rules for Restricting Noise in Areas and Rooms of Industrial Plants."

The health standards and rules establish: maximum permissible levels of noise at work sites in rooms and areas of industrial plants which create noise, and at the boundary of their grounds; conditions and rules of measuring standardized values; basic measures for decreasing noise levels and preventing the harmful effect of noise on man.

Standardized noise parameters are levels of mean square values of sound phenomena (in decibels, L) in octave bands with geometric mean frequencies of 63, 125, 250, 500, 1000, 2000, 4000, 8000 Hz, determined according to the formula:

$$L = 20 \lg \frac{P \ N/m^2}{2 \cdot 10^{-5} N/m^2} dB,$$

where $2 \cdot 10^{-5}$ N/m^2 is the threshold value of mean square sound pressure. (For a tentative evaluation of noise, the general level, measured according to sound meter scale A, called "the level of sound" in dB A can be used.)

Permissible levels of sound pressure in octave frequency bands and levels of sound for work sites in factories and in the areas of industrial plants are given in Table 6 with corrections according to Table 7. Corrections for octave levels of sound pressure and levels of sound apply to the character of sound and its total effective time. /34

Noise is measured in work sites at the ear level of the worker with not less than 2/3 of the standard equipment in typical operation. The number and location of measurement points in shops are:

a. for shops with uniform equipment at not less than 3 work sites in the central part of the shop;

b. for shops with grouped uniform equipment at a work site in the center of each group; /35

c. for shops with mixed arrangements of various types of equipment at no less than three work sites for each type of equipment.

TABLE 8

SOUND METER SPECIFICATIONS

Type of Instrument	Frequency Range, Hz	Variation of Frequency Characteristics, dB	Correction of Frequency Characteristics	Range of Measured Levels	Measurement Errors of Sound Meter	Scale Limits dB	Calibration of Noise Meter	Power Supply	Microphone On	Outer Filter On	Weight, kg
Sh-3M (USSR)	50-9000	14	A.B.C.	25-130	±3	-6÷+10	Electric	49-SAMTsG batteries 0.25 (2 pieces)	MD-59	ASh-2m Analyzer Only	5.5
Sh-63 (USSR)	40-10,000	±3.5	A.B.C.	30-140	±2	-5÷+10	Electric and Acoustic	1KS-U-3 batteries (3 pieces)	MD-38 Shch	PF-1 Filter	4.2
2203 (Denmark) "Bruel and Kjer"	20-20,000	±1	A.B.C. and Linear	22-134	±2	-10÷+10	Same	—	Capacitor 4131	1613 Filter	2.7
1400 (England) "Dow"	25-8000	—	A.B.C.	24-140	±2	-6÷+10	—	—	—	—	6.8
1551-C(USA) "General Radio"	20-8000	—	A.B.C.	24-150	—	-6÷+10	—	—	—	—	3.5
1408-E (England) "Dow Instruments"	43-8000	±3	A.B.C.	24-140	—	—	Electric and Acoustic	—	Crystal	1464A Filter	2

TABLE 8

SOUND METER SPECIFICATIONS (Continued)

Type of Instrument	Frequency Range, Hz	Variation of Frequency Characteristics, dB	Correction of Frequency Characteristics	Range of Measured Levels	Measurement Errors of Sound Meter	Scale Limits dB	Calibration of Noise Meter	Power Supply	Microphone On	Outer Filter On	Weight, kg
-2(GDR)"RFT"	50-12,500	±2	A.B.C. and Linear	40-120	—	—	Same	Batteries 1,2 V 1-4 amp 1,2 V 2-4 amp (per 1 piece)	Capacitor	01-101 Filter	1.8

TABLE 9

SOUND SPECTRUM ANALYZERS AND BAND FILTER SPECIFICATIONS

Instrument Model	Kind of Instrument and Width of Pass Band	Range of Analyzing Frequencies, Hz	Number of Band Filters	Reading	Power Supply	Weight, kg
ASh-2M (USSR)	1/3-octave Analyzer	37-11,000 (8 octave)	25	On pointer-type instrument, calibrated from +2 to -30 dB	From 127/220 V line, 50 Hz	[illegible]
PF-1 (USSR)	1/2-octave Filter	42-11,000 (8 octave)	16	On pointer-type instrument of sound meter	—	32
S-34 (USSR)	1/3-octave Spectrometer	45-23,000 (9 octave)	27	On screen of cathode ray tube, calibrated from 0 to 35 dB	From 220 V line, 50 Hz	2[illegible]0
1613 (Denmark) "Bruel and Kjer"	Octave Filter	20-45,000 (11 octave)	11	On pointer-type instrument of sound meter	—	2.5
1464A (England) "Dow Instruments"	Same	32-8,000 (8 octave)	8	On pointer-type instrument of sound meter	—	1
2112 (Denmark) "Bruel and Kjer"	1/3-octave and octave Analyzer	25-40,000 (11 octave)	33 and 11	On pointer-type instrument	—	5
"DFB" (GDR)	Octave Filter	20-16,000 (10 octave)	10	On pointer-type instrument of sound meter	—	3

/37

TABLE 10

COMPARATIVE TABLE OF AUTOMATIC RECORDER SPECIFICATIONS

Type of Instrument	Frequency Range	Dynamic Range	Recording Range	Paper width mm	Recording Speed mm/sec	Input Impedence kohm	Power Supply V
N-110 (USSR)	20 Hz-200 kz	25, 50, 75	10	50	50-1000	40	220 V, 50 Hz
2305 (Denmark) "Bruel and Kjer"	2 Hz-200 kz	10-75	5m V-100 V	50	4-2000	16	220 V, 50 Hz

TABLE 11

OSCILLOGRAPH SPECIFICATIONS

Type of Instrument	Operating Frequency Band, Hz	Number of Channels	Kind of Recording	Recording Speed, mm/sec	Width of Photographic Film, mm	Time Mark, sec.	Input W	Power Supply, V	Weight kg
N-105 (USSR)	to 1800	12	On photographic film and ultraviolet paper	0.5-10,000	35-60-100-120	For observation 2-0.2-0.002	450	125/220	35.5
N-109 (USSR)	to 1200	20	Same	12-2500	120 and 300	1-0.1-0.01	500	220	51
M-1950 (England)	to 6000	18	On ultraviolet paper	1000	150	For equipment 10-0.01	600	100/250	51
GNT-621 (USA)	to 6000	14	—	2000	150	None 0.1-0.05	—	115	12.4

Noise in industrial plants with no noisy equipment — in observation and remote control rooms — is measured, with windows closed and mechanical ventilation switched on, at three points at distances of no less than 2 m from enclosing structures, and for small booths and rooms — in the middle of the booth or room.

Noise in areas adjacent to buildings with standardized noise levels was measured /38 at a distance of 1.2 m above the surface of the ground at points located 2 m from the walls of the building.

Noises in parks, hospitals, and santoriums adjacent to industrial plants and their grounds are measured at an altitude of 1.2 meters from the surface of the ground at points located 2 m from the boundary of the area or buildings, with structures or green belts arranged along the boundary.

Noise measurements to reveal the noise regime in the areas are made throughout the day with intervals of no more than 2 hours at points determined by a coordinate grid. Mesh dimensions of the coordinate grid and the graph of measurement hours is determined by a special program coordinated with local health service members.

Tables (8 - 12) with specifications are given for various brands of sound meters, automatic recorders, analyzers and microphones.

TABLE 12

MICROPHONE SPECIFICATIONS

Model of Instrument	Frequency Range, Hz	Dynamic Range, dB	Variation of Frequency Characteristics, dB
MK-5A (USSR)	20-20,000	38-152	4
MK-6 (USSR)	20-40,000	38-152	5
MIK-6 (USSR) (with amplifier-feed device)	20-20,000	34-156	3
MD-59 (USSR)	50-20,000	—	8
4131 (Denmark) "Bruel and Kjer"	20-18,000	15-146	±2 dB of relative sensitivity at frequency of 400 Hz
4133 (Denmark "Bruel and Kjer"	20-40,000	32-160	Same
4135 (Denmark) "Bruel and Kjer"	30-40,000	64-174	±2 dB of relative sensitivity at frequency 400 Hz (without protective screen)

Hygienic Characteristics of Industrial Noise

In nearly all branches of industry where the work process is accompanied by noise, its physical parameters have been determined and a study made of the effect of noise on the human organism.

There is information on the occupational deafness of workers in metallurgical and machine-building industries in the works of A. V. Zakher (1926), D. I. Bakhrakh and B. Ye. Sheyvekhman (1949) Prolingheuer (1956) and others. Changes in the /39 organism and especially pronounced deviations in hearing were noted among: boiler-makers (G. S. Tramvitskiy, 1925; S. S. Grobshtein and A. V. Kugaro, 1931; Ya. S. Temkin, 1931, 1957; and others), weavers (Ye. N. Malyutin, 1896; B. Ye. Sheyvekhman, 1938; S. S. Vishnevskaya and S. I. Gorshkov, 1960; L. L. Al'pern, 1962; and others), nailers (N. N. Lozanov and S. F. Gamayunov, 1929; L. A. Kozlov, 1929; A. M. Medovoy, 1932; M. L. Khaymovich, 1960; and others), rail and water tansport machinists and firemen (A. S. Sakovich, 1928; P. S. Uroda, 1929; M. Kh. Yelin, 1934; I. I. Slavin, 1955; A. M. Volkov, 1958a; L. Ya. Skuratova, 1961), as well as workers in other occupations.

According to these studies, changes in the organism of workers, due to the effect of industrial noise, depend on the character of that noise, the direction of sound, the duration of its effect during the working day upon the work of inspectors in a noisy industry, individual sensitivity as well as age, sex, and general condition of the workers. However, published works often lack accurate physical characteristics of the noise, while it has been proven (L. Ye. Milkov, 1963a; E. A. Drogichina et al., 1965; S. V. Alekseyev, 1965; G. A. Suvorov, 1965; and others), that even small changes in the quality of a noise stimulus lead to fundamentally different reactions of the organism. Therefore, in industrial research, along with finding sources of noise formation, noise must be evaluated separately from other industrial factors. Each factor must be measured separately and the results compared with available health standards (L. N. Shkarinov, 1964). At the present time, there are a large number of works giving an idea of the noise factor in various branches of industry. It is important to consider some of them.

Noise in machine construction. There are factories in the present machine-construction industry in which noise reaches an extremely high level, exceeding the permissible levels by 25 - 39 dB. The highest level of noise is in cold upset

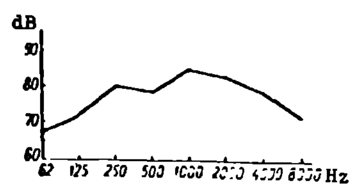
(101 - 105 dB) and nailing (104 - 110 dB) departments, weaving shops (97 dB), and in weld polishing departments (115 - 117 dB). One of the main processes in machine construction and a number of other industries is metal working by cutting. The research conducted by G. Z. Dumkina (1965) showed that turret lathes and automatic machines for working comparatively complex parts which require the use of various /40
cutting instruments generate noise with an intensity of 82 - 99 dB, with maximum sound energy in the frequency range of 250 - 4000 Hz (Table 13). Levels of noise intensity of the automated sections is higher than that of the lathes and exceed permissible limits in the high-frequency range of the spectrum (Figure 13).

TABLE 13

NOISE IN TURRET-LATHE SHOP

Section	Noise Emitter	General Level, dB	Predominant Frequency, Hz
Turret	Work of lathe without load	70 - 73	250 - 800
	Lathe in operation	82 - 87	250 - 2000
Automatic	Work of lathe without load	73 - 75	250 - 800
	Lathe in operation	92 - 99	250 - 4000

Figure 13. Noise spectrum of automatic machine area. General level 93 dB. Vertically - noise level.



Noise in shipbuilding shops. As shown by Yu. S. Karyukayev (1969), many technological processes in shipbuilding shops can be sources of intense noise: work with mechanized hand tools; work of special technological equipment (lathes, crushing plants, tumbling barrels, etc.).

In work with mechanized hand tools, as a result of structural vibration, intense air noise develops in the sound range. The character and intensity of noise are determined by percussion processes of working metal with chisel, mandrel, abrasive cutter, etc. Noise from the engine discharge of pneumatic machines is considerably camouflaged; only when thick-walled structures are drilled with low-cycle power machines does discharge noise come to the forefront.

The general level of cutting noise is 118 - 130 dB; the most intense levels of noise are found in cutting in closed areas — 130 dB. Noise spectra for cutting and riveting under various conditions are given in Figure 14.

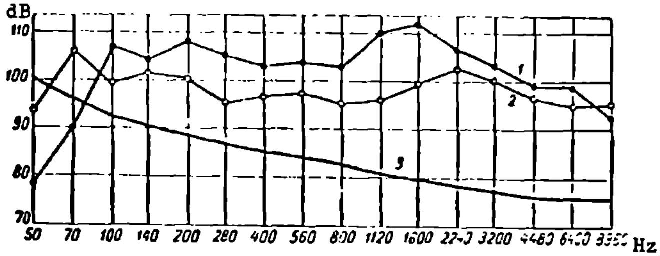


Figure 14. Noise spectra of cutting with a pneumatic hammer (0.5 m from source): 1 - in closed space, general level 130 dB; 2 - cutting of a flat section, general level 119 dB; 3 - permissible level of noise (standard No. 205-56 of February 9, 1957).

The spectrum of grinding noise is somewhat similar to cutting and riveting noise (Figure 15).

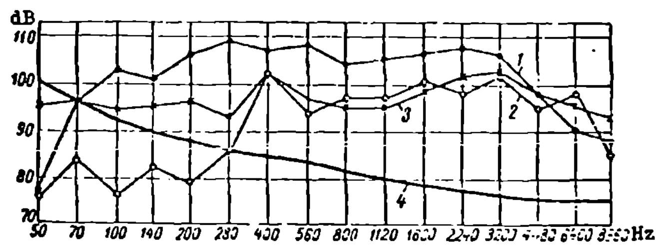


Figure 15. Noise spectra in working metal with a grinding machine (0.5 m from source): 1 - in closed area of section, general level 117 dB; 2, 3 - working a flat structure, general level 102 and 110 dB; 4 - permissible noise level.

Drill presses generate much lower-intensity noise than other pneumatic instruments (Figure 16).

Analysis of the noise levels of a large number (28 kinds) of pneumatic instruments, used in assembly work, shows that, on the average, the level of noise does not descend below 85 dB, but neither does it exceed 105 dB with high-frequency characteristics of the spectrum. In straightening and assembly work, hammer blows on masses of metal cause peak noise levels from 123 - 129 dB and higher. Metal blanks falling into a bunker generate noise which reaches levels of 98 - 106 dB. /42

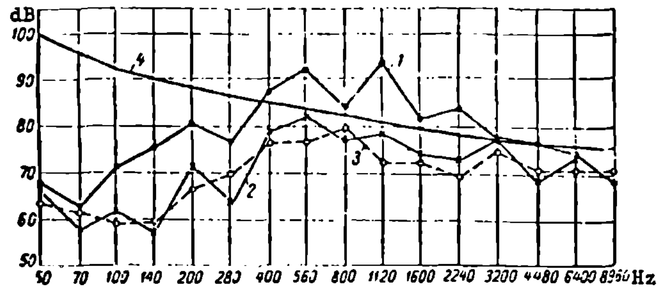


Figure 16. Noise spectra of RS-22 drill press (0.5 m from source): 1 - drilling thin-wall structure, general level 79 dB; 2 - drilling side of ship, general level, 84 dB; 3 - drilling large component, general level 84 dB; 4 - permissible noise level.

An analogous picture is also observed in the work of metal shears. Noise is often increased by improper construction of assembly areas, which can be in the form of hollow volumes of large dimension. Noise levels are increased by crushers, ventilator systems, and other equipment.

Noise in reinforced concrete products plants. One of the most important measures to improve working conditions of construction-industry workers is reducing the industrial noise in reinforced concrete structures plants. According to the data of A. P. Pronin (1967), noise levels in these factories exceed health standards (Table 14).

An analysis of noise spectra at work sites showed that the harmful effect of noise on the organism of molders is determined primarily by a vibration frequency of 50 Hz, which is not clearly pronounced in the noise of most plants, but in large amounts is present in the spectrum of high-frequency components with a random character and occupying a wide-frequency band. On the basis of experimental research, the author feels that the loudness of the noise of a vibrating platform can be reduced three times by insulating the debalanced point with steel springs; the number of high-frequency components of the spectrum will be essentially decreased.

TABLE 14

INDUSTRIAL NOISE LEVELS AT THE WORK SITES OF MOLDERS IN COMPARISON WITH HEALTH STANDARDS

Plant	Unit and Measurement Point	Noise Level dB	Noise Level According to Standard dB	Excess of Standard dB
Reinforced concrete sleeper plant No. 1	At vitration table No. 1	115	90	25
	At vibration table No. 3	108	91	17
	At vibration table No. 1 when vibration table No. 3 is in operation	103	95	8
Piano wire concrete sleeper section in rubble-sleeper plant	At vibration table, both molds empty	119	93	16
	At vibration table, molds half filled	115	93	22
	At vibrator, both molds filled with concrete	110	94	16
Reinforced concrete sleeper plant No. 2	New department at vibrating area 5917A	113	98	15
	Old department at vibrating area SM-476	111	96	15
	Open polygon at vibrating area SM-476	113	100	13
Reinforced concrete structures plant No. 7	Vibrating area SM-476 for manufacturing paving	114	94	20
	Vibrating area SM-476 for manufacturing sleepers	119	89	30
Reinforced concrete structures plant No. 2	Vibrating area SM-868, molds empty	120	83	37
	Vibrating area SM-868, molds filled with concrete	111	89	22
Silica-calcite plant No. 1	Vibrating area SM-476 No. 1	114	100	14
	Vibrating area SM-476 No. 2	117	88	29
	Vibrating area SM-478 No. 3	112	94	18

Noise at machine calculating stations. A study of noise at machine calculating /43 stations, conducted by V. K. Markushkina (1968), showed that the general level of noise in the departments varied from 75 to 92 dB, is of high frequency, and exceeds the maximum permissible levels in the frequency range from 4000 to 8000 Hz by 25 - 37 dB. Sources of noise are: the numerous pinion gears, electric motors, printing mechanisms, contactors, relays, perforating and ventilating devices.

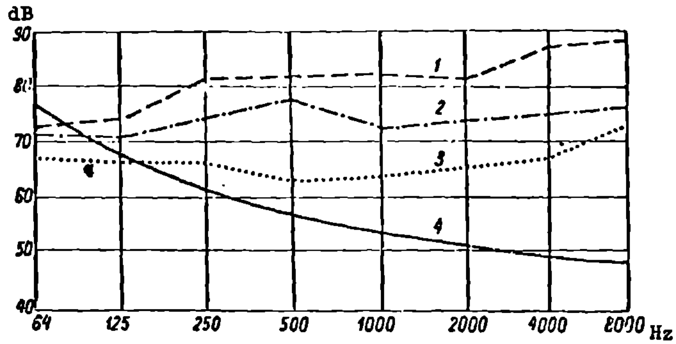


Figure 17. Noise spectra at machine calculating stations: 1 - perforation area; 2 - calculator areas; 3 - tabulation areas; 4 - permissible noise level (PS-55); horizontally - frequency; vertically - level of sound pressure. Levels L: 1 - 92 dB; 2 - 83 dB; 3 - 92 dB.

Vibrations developing during the operation of these machines is transmitted to the thin walls of the bodies and is emitted in the form of noise to the surrounding /44 medium (Figure 17).

Experiments conducted for the purpose of combatting noise (sound-proof linings and coverings) have made it possible to reduce noise more than one half (loudness), i.e., 10 - 15 dB. The noise spectrum is also changed by the elimination of high-frequency components, while in unlined rooms the standards are exceeded by 30 dB,, or 7 - 8 times louder (Figure 18).

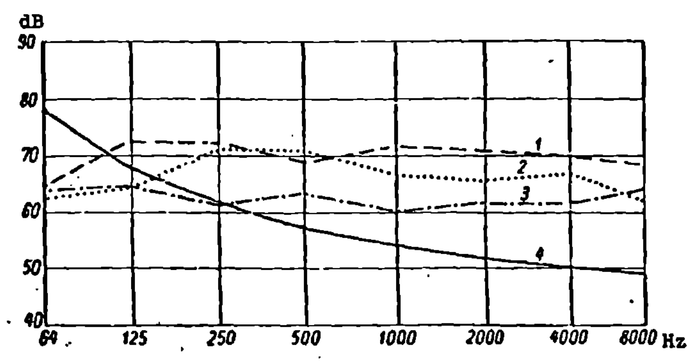


Figure 18. Noise spectra at machine calculating stations after the installation of sound-proof linings. Symbols same as in Figure 17. Levels L: 1 - 81 dB; 2 - 77 dB; 3 - 75 dB.

Our country is the first in lumber-preparing and wood-working industries: a study of working conditions, conducted by E. I. Gol'dman (1962), showed that the primary source of logging noise is from electric and gas saws. The noise level in the operation of a K-6 electric saw is: without load, 82 - 85 dB; sawing, 85 - 90 dB. Frequencies of 1600 - 2000 - 3200 Hz predominate in the spectrum (Table 15).

TABLE 15

NOISE LEVELS OF GASOLINE POWERED SAWS

Type of Saw	General Noise Level, dB		Predominant Frequencies, Hz	Excess of Maximum Permissible Level, dB	
	Without Load	Sawing		Without Load	Sawing
Kama-1	88-90	103-106	800-1010-1200	—	8-21
Ural-10	87-89	102-106	408-500-800-1000	—	3-16
Ural-10	96	112-114	120-600-800-1000	3-5	4-28
Druzhba-60	87-88	95-99	800	—	2-14

In skidding lumber (mechanized transfer of trees from the place they were felled to where they are loaded onto lumber carriers), the noise is created by logging winches and tractors. In winch operation, the noise is due to the diesel engine and varies from 103 to 108 dB. The maximum sound energy falls in low and middle frequencies. Winch noise exceeds the permissible level in the low frequency range by 3 - 5 dB; middle frequencies, by 10 - 15 dB; high frequencies, by 10 - 18 dB.

The noise from logging tractors also is due to the operation of diesel engines (Table 16).

It is evident from the data in Table 16 that noise increases in proportion to the increased speed of the tractor, reaching 109 - 117 dB. The noise spectrum of tractors is marked by a wide range of frequencies (Figure 19), the sound energy maximum falls in the low-frequency range.

Research conducted at modern wood-working plants in the city of Omsk by A. P. Mikhayluts (1968) has shown that the general level of noise intensity at work sites in sawmill departments varies from 93 to 100 dB; the noise is wide-band with a maximum sound energy in the middle (320 - 400 Hz) and high (1600 - 3200 Hz) frequency range (Table 17). /46

TABLE 16

NOISE LEVELS OF LOGGING TRACTORS

Work Regime of Tractors	General Level of Noise in Tractor Cabins, dB		
	TDT-40, 1960 Model	TDT-60	S-80
Idling (standing)	96	93-103	96
Second gear	96-97	107-112	105-107
Third gear	97-110	102-115	106-110
Fourth gear	99-110	105-117	106-111
Fifth gear	102-110	109-117	—

TABLE 17

LEVELS OF INTENSITY AND THE SPECTRAL CHARACTERISTICS OF NOISES CAUSED BY SAWMILL EQUIPMENT (after A. P. Mikhayluts)

Equipment, Measurement Site	General Level of Intensity, dB		Frequencies (in Hz) with Maximum Sound Energy	Excess of Maximum Permissible Level, dB (in frequencies)
	Without Load	In Operation		
RD-75-2 mill gang-saw (work site of saw operator)	93	—	320-400	10 (1600)
RD-75-6 mill gang-saw (work site of saw operator)	—	97	320, 2000-6400	19 (6400)
DOKa lumber unit (work site of operator)	—	98	250, 1600-2000	26 (6400)
LPDK lumber unit (work site of operator)	—	93	320, 2000	18 (3200)
DSK lumber unit (work site of operator)	—	92	320, 2000	10 (3200)
DTs trimmer (work site of operator)	99	—	1000, 1600-2000	22 (1600)

Figure 19. Noise spectra in tractor cabins: 1 - TDT-40; 2 - TDT-60; 3 - S-80.

In lathe departments of carpentry shops in wood-working and house-building combines, the levels of noise intensity are 90 - 97 dB and 92 dB, respectively; the noise is wide-band with maximum energy at mean frequencies (320 - 350 Hz) and high (1600 - 2000 Hz) frequencies (Table 18).

TABLE 18 /47

LEVELS OF INTENSITY AND SPECTRAL CHARACTERISTICS OF NOISES OF WOOD-WORKING MACHINES (after A. P. Mikhayluts)

Equipment	General Level of Intensity, dB		Frequencies (in Hz) with Maximum Sound Energy	Excess of Maximum Permissible Level, dB (in frequencies)
	Without Load	In Operation		
UPA Paver	—	93	640, 1200, 1600	13 (1600)
N-12-6-150 Planer	95	—	320, 640, 1000	11 (1600)
SK-15 Planer	—	98	125, 508, 806	14 (800)
N-12-6-150 Planer	—	100	640, 2000, 3200	27 (3200)
N-12-5-7 Planer	94	—	500, 1000	9 (1600)
SD-8 Scriber	100	—	1000	15 (1600)
SR-5 Scriber	108	—	400	18 (1600)
ShD-12 Band-cutting Machine	98	—	403, 1260, 1600	16 (1600)
ShO-6 Band-cutting Machine	—	98	50	—
Milling Machine F-4	—	97	320, 500, 800	13 (800)

Noise intensity at the work cites of lathe machine operators varies from 90 to 112 dB and depends on the kind, and brand of the lathes and partially on their arrangement in the shop plan. Industrial noise exceeds levels permitted by health standards by 9 - 15 dB without load and 7 - 27 dB in operation, primarily in the high-frequency range of 1600 - 3200 Hz.

Noise in the textile industry. The overwhelming majority of production processes in cotton spinning and weaving shops are accompanied by the formation of noise (L. Ya. Burlova, A. F. Lebedeva, A. V. Tarasova, 1963). The primary sources of industrial noise are the equipment in spinning and especially weaving factories (the beating mechanism of the weaving machine, strokes of shuttle, heald, gear tappets, etc.), the operation of fans and conveyers within the shop.

Spinning-weaving factory noise usually is of a complex spectral composition and, in a number of cases, exceeds the health standards (Table 19).

TABLE 19

SPECTRAL CHARACTERISTICS OF NOISE IN DEPARTMENTS OF SPINNING-WEAVING FACTORIES

Shop or Department	Intensity Level of Noise, dB	Permissible Level, dB	Noise Spectrum with Maximum Sound Energy
Scutching	93-97	85-90	Middle-frequency, with maximum intensity around 400 Hz
Combing	82-85	85-90	Low and medium-frequency, with maximum intensity between 160 - 600 Hz
Carding-combing and ribbon machines	92	85-90	Low and middle-frequency; predominance of frequencies from 200 to 1200 Hz
Smoothing	93-99	75-85	Middle and high-frequency; predominance of frequencies of 5500 - 6500 Hz
New Machines:			
RTT-132	85	75-85	Medium and high-frequency; with maximum intensity between 400 and 4000 Hz
RTT-132-2	83	75-85	
RTT-168	91	75-85	
Spinning	95-96	75-85	Same
New spinning machines	80	75-85	Same
Weaving (mechanical machines)	95-105	75-85	Same
ATS-5 and AT-100 automatic machines	94-96	75-85	High and middle-frequency, with maximum level at frequencies from 1280 to 3535 Hz.

As can be seen from Table 19, the highest level of noise is observed in weaving departments — 94 - 105 dB; in shops with ATS-5 and AT-100 automatic weaving machines, the noise intensity is somewhat lower, 94 - 96 dB.

High noise levels are noted in artificial fiber factories (spinning, winding shops), where, as in the textile industry, a large number of workers are employed.

A study of working conditions in clothing factories, conducted by O. M. Rukavtsova (1968) (Table 20), has shown that the general levels of noise at work sites of sewing machine operators working at stitching machines (97, 22A, 22B, 22C, 55, 428 and other classes) are 90 - 95 dB with maximum sound energy in the 1000 - 8000 Hz range, with an excess of 12 - 16 dB over the standard level in the high frequency range. Noise at work sites from winding machines (51A, 63 kl and others) reaches 90 - 91 dB with distribution of sound energy in a wide range of frequencies with the maximum at low (250 Hz) and high (2000 - 8000 Hz) frequencies. There is an excess of 8 - 10 dB at a 8000 Hz frequency. /48

Total levels of intensity at work sites of sewing machine operators working at overcast-stitching machines (classes: 761, 7-M, 85, TM-1, 26-"Zigzag") are 92 - 94 dB. In the noise spectrum, frequencies of 2000 - 8000 Hz predominate. Noise exceeds the standard level by 7 - 16 dB.

In the operation of semiautomatic class 27 and class 25A machines, noise with a general level of 89 - 92 dB is created; maximum sound energy occurs in 4000 - 8000 Hz frequencies with an excess of 13 - 15 dB over the permissible values. /49

General levels at work sites of press operators (PSP press) reach 94 dB; high frequencies of 2000 - 8000 Hz predominate in the spectrum.

A characteristic of the noises studied is their intermittance, as a result of the periodicity of stitching. For stitching work lasting 4 - 12 seconds, there must be an interruption of from 3 to 7 seconds, during which time the operator prepares details for the next stitching (puts aside sewn work, takes others from the conveyor, puts it under the machine foot). Noise parameters also change accordingly. The most intense noise is generated during stitching; during the interruptions, intensity at work sites is reduced to the background level. The

TABLE 20

LEVEL OF INTENSITY AND SPECTRAL CHARACTERISTICS OF SEWING SHOP NOISES

Shop Equipment	Speed (no. of r.p.m. of main spindle)	General Level dB	Frequencies with Maximum Sound Energy of 1000-8000 Hz	Excess Over Maximum Permissible Level 12 (8000) dB/Hz
Multipurpose machine (class 97)	to 5000	95	1000-8000	12 (8000)
Quilter (761 class)	600	94	2000, 4000, 8000	16 (8000)
Fastener (73 class)	1500	93	2000, 4000, 8000	16 (8000)
Braid applier (428 class)	2500	91	2000, 4000, 8000	16 (8000)
Button holer (25A class)	1400	92	4000, 8000	13 (8000)
Chain stitcher (55 class)	2000	90	2000, 4000, 8000	16 (8000)
Hemmer (85 class)	2500	92	500-8000	7 (8000)
Overcaster (51A class)	3500	90	2000, 4000, 8000	8 (8000)
PMZ machine (class 22A)	3500	94	2000-8000	13 (8000)
Button machine (27 class)	1200	89	1000, 4000, 8000	15 (8000)
Quilter (M-7)		92	4000, 8000	14 (8000)

difference between the interrupted noises, developing during machine operation, and the background is 10 - 15 dB; according to time-study observations, 60% (more than four hours) of the working time is involved with stitching.

<u>Noise in stamping factories</u>. Stamping factories occupy a leading place in industry. Noise, generated by press equipment, is pulsed noise with a complex time structure. As shown by Ye. B. Reznikov (1966), in operation the majority of presses generate pulsed noise with a repetition rate of 15 - 60 pulses/min., which, along with great intensity and a high-frequency spectrum, has unfavorable time characteristics (Table 21). /50

TABLE 21

CHARACTERISTICS OF PULSED NOISE, GENERATED BY PRESS EQUIPMENT IN STAMPING SHOP (after Ye. B. Reznikov)

Source of Noise	Average Power of Sound Pressure for the Period (Relative Power 10-12 W/m^2) dB	Level of Sound Pressure According to Exponential pulse Sound Meter 1412, dB	Level of Sound Pressure According to Sound Meter SH-63, dB	Time of pulse Build-up (in msec) with 0.63A(1)
"Veyngarten" Co. Press	112	117	103	50
"Shuller" Co. Press	95	115	97	28
"Kirkhayt" Co. Press	107	116	101	70
"Pal'e" Co. Press	126	129	109	100
"K-16" Press of "Metallist" Factory	102	110	95	120
"Tyumler" Co. Automatic Press	98	118	98	21
"Pedn" Co. Press	98	120	97	60

(1) 0.63A — the time during which the amplitude increased to 0.63 from the amplitude of the constant level assumed to be 1.

Noise levels, measured by sound meter SH-63 at work sites was 94 - 103 dB, and when measured by the 1412 "Bruel and Kjer" sound meter — 109 - 129 dB, i.e., in all percussive processes peak values of the noise level are actually 10 - 20 dB higher than indicated by an ordinary sound meter, and therefore, standard recommendations SN-245-63 for measured pulsed noise have substantial defects, with errors in their physical evaluation.

For a number of years at the occupational health department of LSGMI, a study has been conducted on the dynamic characteristics of noise, the characteristics of their perception, and their effect on the organism both in experimental and natural conditions in industry. Accumulated experimental experience makes it possible to distinguish and define the most important characteristics of unstable noise. There was also an attempt made to develop a method of evaluating unstable noise (G. A. Suvorov et al., 1968; Ye. Ts. Andreyeva-Galanina, G. A. Suvorov, A. M. Likhnitskiy, 1968). Research conducted at a number of plants with equipment generating pulsed noise indicates that the methods of measuring and evaluating pulsed noise can be used effectively in practice. /21

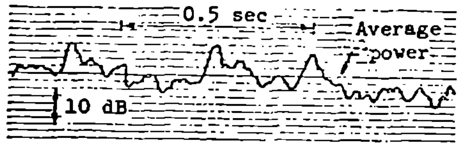


Figure 20. Curve showing dependence of pulsed noise intensity on time, registered by automatic recorder 2305, and medium power 2417 voltmeter. Background level, 94 dB.

Thus, the study we made of the characteristics of the noise of stamping departments in shoe factories with the help of automatic recorder No. 2305 — which operated in a regime with a stylus speed of 1000 mm/sec, paper speed of 100 mm/sec and a time constant of 20 msec — showed that noise at the work site of the stamper consists of a series of pulses lasting 1.6 sec, including 4 - 5 pulses with a repeat period of 0.4 seconds and with intervals varying from 1 to 5 seconds between series of pulses, which is due to the characteristics of the specifications. The intensity of noise in the pause, measured by a standard sound meter, is 94 dB. Noise pulses had an exponential form with a time build-up of 20 msec, a decay time of 100 msec, and instantaneous power (intensity) of 115 dB per pulse. Average power determined with a 2417 voltmeter (Bruel and Kjer) of random noise is 98 dB (Figure 20). A noise study on a 4420 statistical distribution analyzer showed that the most probable noise intensity corresponds to the average power. Spectral analysis, conducted on a three-octave No. 2112 spectrum analyzer together with a No. 2305 automatic recorder, showed that the averaged noise spectrum is almost equally distributed in the three-octave bands from 40 to 2000 Hz.

The method developed by the authors to evaluate pulsed noise is intended to be used both with experimental and industrial equipment; however, it does not /52
exclude the possibility of using other methods to study random noises.

It is evident that citing exhaustive data about the noise factor in all branches of the national economy is a back-breaking task; therefore, in this chapter we have omitted the noise characteristics of a number of industries. Nevertheless, the data presented thoroughly illustrate the parameters and character of the noise stimulus on which the effect on the human organism largely depends.

We must note that, at the present time, we have adopted in this country GOST* 11870-66 "Machines. Noise Characteristics and Methods of Determining Them," which is used to establish machine noise characteristics, and which obliges all manufacturers of machines and equipment to test the products they issue and evaluate the noise which develops in operating these machines. This GOST provides the requisite information, so that each factory-produced machine carries its own noise characteristics, making it possible to compare similar and different machines in terms of noisiness and serving as an objective criterion for evaluating their technical perfection and quality of performance.

*Translator's Note: GOST = State Standard.

CHAPTER II /53

TECHNIQUES OF STUDYING THE EFFECT OF INDUSTRIAL NOISE ON THE ORGANISM AND NECESSARY EQUIPMENT

The Acoustic Complex and the Order of Conducting Experiments

Successful study of the effect of industrial noise on the organism and the development of effective preventive and therapeutic measures require vast experimental work in laboratories provided with the latest acoust: : and physiological equipment.

Soviet and foreign literature presently contains a description of various types of reverberation and anti-reverberation chambers primarily intended for technical purposes.

We must note that a reverberation chamber is called a sound- and vibration-proof room, in which conditions are created to reflect the sound field; according to standard requirements, the room is considered suitable for measurements in a reflected sound field if the variation between the levels of sound pressure in the frequency range of the measurements does not exceed 2 dB.

An anechoic (anti-reverberation) sound chamber must be a room well insulated from external sounds and vibrations in which sounds are almost completely absorbed when they strike the dampened surfaces of the room.

An anechoic sound chamber can be considered satisfactory if — when the distance from all points of measurement (measuring radius) to the acoustical center of the source is divided in half — the levels of sound removal in the frequency range of the measurements increases no less than 5 dB, and — when this distance is doubled — it is reduced no less than 4 dB.

Since in conducting physiological experiments studying the effect on the organism of various spectral and time characteristics, it is necessary that the signal supplied be undistorted, in medical practice similar experiments require construction of sound-deadening chambers.

Wedge-shaped or cone-shaped constructions are usually used to line anechoic /54
sound chambers, as well as layered constructions.

In wedge- or cone-shaped constructions, soundproof linings are usually made of Mipor, fiberglass mats, packed Kapron fiber, glass separator plates, polyurethane foam or staple fiberglass. The effective volume of the chamber is in this case small in comparison with the volume of the entire construction, but it is very expensive. Similarly finished acoustic chambers are used for physical measurements and are described by a number of authors.

As an example, we cite the anechoic sound chamber designed for one of the Scientific Research Institutes. It is a rectangular box with internal dimensions of 14.3 x 12.3 x 7.55 m. The walls are brick, 65 cm thick; the ceiling is reinforced concrete, at least 50 cm thick. The floor is highly reflective concrete. The walls, door, and ceiling of the chamber are lined with soundproof constructions, fiberglass wedges 100 cm long; the base is 20 x 20 cm. The air gap between the base of the wedges and the wall is 15 cm. The calculated variation of the sound field in the chamber is from ±2 to ±3 dB. The coefficient of soundproofing the wedge-shaped constructions is not less than 0.9, the anticipated error of the sound level pressure measurement is from ±3 to ±4 dB.

Another type of absorbing structures is deadened hollow resonators. The most common soundproof constructions of the resonance type are perforated panels which are placed at a certain distance from the hard walls of the chamber.

Most often used in constructing layered sound-deadening chambers are Kapron fiber, slag wadding, staple fiberglass, thick felt in a phenolic bale, etc.

Two anti-reverberation chambers were created in the Department of Occupational Medicine of the Leningrad Medical Institute of Health and Hygiene which were equipped with acoustics equipment to create stable and pulsed noise of various parameters (Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, G. A. Suvorov, 1963, 1965; Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, G. A. Suvorov, A. V. Kadyskiy, 1966). One rectangular chamber with dimensions of 2.2 m (length) x 1.5 m (width) x 1.9 m (height) was placed inside a room 87.1 m^3 in volume with standard sound insulation. As can be seen in the drawing (Figure 21), in the chamber the internal enclosures (walls and ceiling) were lined with perforated plywood sheets (plates) 4 mm thick. /55
The sheets were fastened 150 mm from the inner wall of the chamber; directly adjoining it was a layer of loose slag 50 mm thick. Between the layer of wadding and the inner wall of the chamber, there is an air layer 100 mm thick.

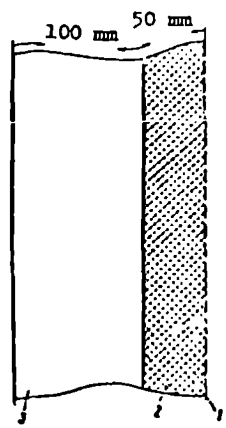


Figure 21. Soundproofing structure of the chamber: 1 - perforated sheets; 2 - soundproofing material; 3 - air layer.

Two kinds of perforated sheets are used: 1) perforated with holes 5 mm in diameter, numbering 360 per 1 m^2, f_0 (resonance frequency) is 500 Hz; 2) perforated with slits 80 mm long and 2 mm wide, distance between the slits is 10 mm vertically and 20 mm horizontally, f_0 (resonance frequency) — 2000 Hz. The floor was covered with porous rubber rugs. This design provides sufficient absorption of high-,

middle- and low-frequency noises and is characterized by an averaging of the curve of sound absorption with a coefficient of 0.8 in a frequency range from 150 to 5000 Hz.

The soundproofing process in the room is also characterized by the time of reverberation T, necessary to reduce sound energy to 60 dB.

This soundproofing construction makes it possible to obtain a time of reverberation of impulse signals for various noise bands from 0.04 to 0.1 seconds (Table 22).

TABLE 22

TIME OF REVERBERATION IN SOUNDPROOF CHAMBER FOR VARIOUS FREQUENCY BANDS

Bands, Hz	Time of Reverberation, Sec
50-80	0.1
101-202	0.08
254-508	0.04
640-1280	0.06
1614-3220	0.08
4060-8130	0.11
20-10,000	0.08

At these values, psychophysically, reverberation does not distort the perception of signals, as the time constant of the ear subsides more slowly than the echo of the signal dies down. The sound field in the chamber has a non-uniformity for /56 white noise of ±3 dB.

All acoustic measurements were made with the assistance of a MK-5A measuring condenser microphone; transient characteristics were recorded by an ENO-1 oscillograph.

The intensity of stable noise was measured by a SH-63 sound meter, and the spectrum — by a sound frequency spectrometer (SZCh) and a SKCh-3 spectrum and frequency characteristics analyzer (ASChKh-1). Sound proofing of the chamber from

internal noises was a two-step problem, as it is separated from internal sources of noise which interfere with conducting the research. Construction of the chamber ensured its soundproofing to 45 dB.

In connection with the small size of the chamber for conducting the experiments, it is equipped with mechanical suction-and-exhaust ventilation. The construction of the ventilating equipment made it possible to reduce the level of noise it generated to 25 dB without the use of complicated acoustic filters.

The room with the second soundproof chamber had a volume of 17 m^3. The walls and ceiling of the chamber were lined with sound-absorbing plates, perforated sheets of plywood backed with a layer of Kapron stripping. To produce an even curve of sound absorption at a level of 0.8 m from 300 to 5000 Hz, perforations in the sheets had a round or slotted shape. The diameter and spacing of the perforations was 4 and 20 mm, respectively. The chamber was not rigidly connected with the walls and ceiling of the room. The sound-absorbing sheets were placed 10 cm from the walls. The distance between the sheets and walls was half filled with air and half filled with Kapron stripping. The floor of the chamber was covered with sound-absorbing rubber rugs 5 mm thick. Time of reverberation of the chamber is reduced to 0.03 - 0.08 seconds, thereby only slightly distorting the time structure of the noise. The configuration of the room must be altered to realize a diffuse field. This was avoided with the help of angular reverberatory plates, mounted on the ceiling (Figure 22), with the use of a special acoustic unit.

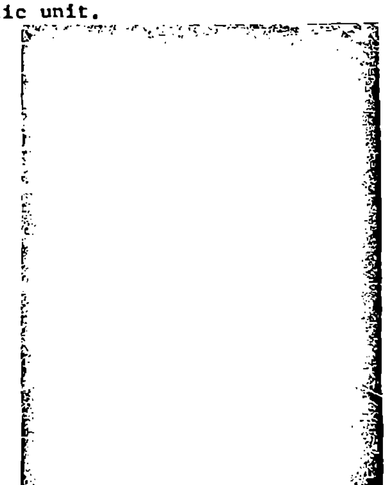


Figure 22. Soundproofing of upper part of the chamber.

The non-uniformity of the field in the area of the subject's head was ±1.5 dB in the entire frequency range under conditions of a plane incident wave.

Noise was reproduced with the help of a "Mag-8" stationary tape recorder with reproduction frequency characteristics from 50 to 10,000 Hz and with non-uniformity of ±1.5 dB.

In studying the effect of certain noise parameters on the organism in the experiment, noises are often reproduced in the chamber with tape recordings. However, there are difficulties which greatly limit the possibility of this technique. This is because the majority of portable tape recorders, produced commercially, have a very small dynamic range, which usually does not exceed 40 dB. /57
We must bear in mind that magnetic tape superposes its own, so-called modulation noise on the noise range, approximately 30 dB lower than the amplitude of the signal. The transmission band of these tape recorders is also very limited with respect to high frequencies of 8 - 10 KH_3. Therefore, when the researcher is faced with the problem of studying the effect on the organism of noise with certain frequency and time characteristics, artificial generation of noise is most valid.

To generate stable noise, the Department developed a method where acoustical equipment was mounted outside the chamber (white-noise generator, 50-watt power amplifier, RC-filters, sound frequency spectrometer, SZCh) (Figure 23).

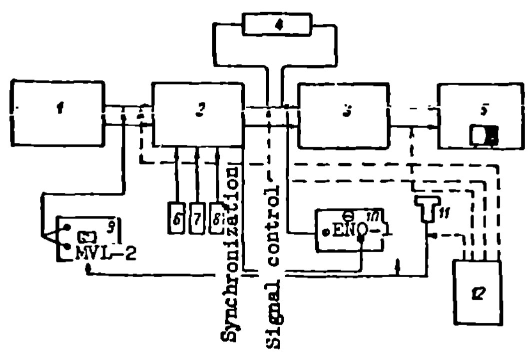


Figure 23. Block diagram of system for generating stable noise: 1 - white noise generator; 2 - electronic gate circuit; 3 - power amplifier; 4 - LC-filters; 5 - two-band unit; 6, 7, 8 - capacitor boxes; 9 - electronic voltmeter; 10 - electron oscillograph ENO-1; 11 - condenser microphone; 12 - sound frequency spectrometer.

Undistorted reproduction of the entire range of sound frequencies with one element — cone or horn shaped with a narrow throat — has not yet been attained simply and economically. The use of two- or three-band devices considerably improved the speaker systems. Two-band equipment is a combination of a conical woofer, reproducing low bands to 600 - 1000 Hz, and a tweeter, corresponding to a range up to 10 or more kHz.

Mounted in the chamber is a two-band acoustical unit of 2, type 1-A-17 high-frequency heads with 2 acoustic lenses — 2 low-frequency, type 2-A-9 heads, placed in acoustic Helmholtz resonators with a volume of 288 liters, filled with commercial wadding. The band is separated by LC-filters with a slope of 12 dB per octave. Output power of the unit is 50 W. There is a white noise generator with an even /58 spectral density in the 20 - 20,000 Hz band. Instantaneous values of amplitudes are subject to the normal law of distribution. An audio frequency spectrometer is used as a band octave filter. LC-filters-analyzers are made in the form of two asymmetrical half-links of an M-shaped structure, activated in series. The width of the transmission band of each filter is 1/3 octave. Parallel activation of 3 filters encompasses 1 octave, the total characteristics of which have a flat peak with a non-uniformity less than ±1 dB.

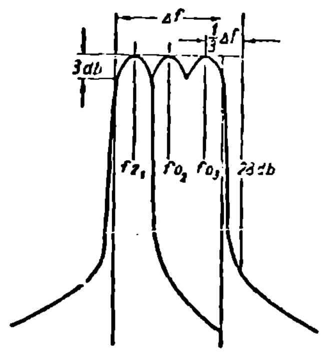


Figure 24. LC-filter of the analyzer: $f_{0_{1,2,3}}$ - geometric mean frequency of the filter; Δf - the transmission band of the filter (Hz).

As shown in Figure 24, attenuation of the filter at frequencies differing from the average frequency of the outer filters, i.e., outside the 1/3-octave band, is 28 dB. Thus in an acceptable approximation, we have a filter with a flat peak, where the transmissions band is distributed between the lower boundary of the lower and upper filter and the upper boundary of the upper filter.

The noise transmitted through the filter also has an even spectral density and the amplitudes are distributed normally. The LC-filters used in the system make it possible to change the spectral density in pertinent parts of the spectrum of low-, medium- and high-frequency noises.

The LC-filter is aperiodic in all parameters, with symmetrical slopes of 6 dB per octave with respect to f_0. In the transmission of noise, an equal density was
produced in the relative bands after the filter above f_0, and below f_0 they had a /59
falling spectral density in proportion to the reduced frequency.

A balanced gate circuit with electronic tubes was used to create noise pulses, multiplying the instantaneous values of stable noise amplitudes by the pulses. The pulses were generated at a frequency set by a stabilized multivibrator, the length and lag behind triggering were set by phantastrons with accelerated regeneration. These "gates" are superior to mechanical switches which have great disadvantages because of inertia. This pulse noise generator makes it possible to work in the range from 10 to 60,000 pulses per minute, where the on-and-off time ratio can also be recorded in wide ranges.

After the gate circuit of the attenuator, the signals proceed to a low-frequency power amplifier with a low level of intrinsic noise (-80 dB), and from there to the acoustic unit.

In the experiments conducted at the Department, we basically studied noise with a primarily rectangular envelope, produced by modulating white noise with rectangular pulses, i.e., noises which fluctuated in amplitude in the form of rectangular pulses, filled by white noise, were used, with the possibility of changing the pulse repetition rate and length over wide ranges.

The amplitude of these signals jumped from 0 to the effective value and back; their parameters were calculated with an oscillograph.

Calculating the energy for one period was reduced to computing the area of the pulses, i.e., multiplying the root mean square of the impulse amplitude by its length.

Several researchers use unmodulated rectangular pulses, i.e., video
pulses. However, the spectrum of such a signal is so broad that no one acoustic /60
device can satisfactorily reproduce it. As a result, transient distortions develop, and, depending on their length, impulses take on a most varied form.

To establish the necessary level of impulse noise intensity, a delayed noise impulse was fed into the chamber. The effective value was established by a standard sound meter (Sh-63). Then an amount was added to the established values to a point where impulse noise is less stable with respect to the off-duty factor.

During the course of the experiment, the time characteristics were under constant acoustical control with the aid of a MK-5 microphone, an ENO-1 oscillograph, synchronized with a trigger generator, and a MVL-2M electronic voltmenter.

In the second soundproofed chamber, the acoustical unit is a system where low and high frequencies are reproduced by verious types of loudspeakers. Section frequency is 800 Hz. The slope of the cut-off is 12 dB per octave.

Type 2A9 dynamic heads mounted on a triangular sheet 100 mm by 200 mm, switched on in cophases, were also used to reproduce low frequencies. The sheet is placed in the corner of the chamber, forming a closed area filled with loose commercial wadding.

The radiation of the reverse side of the diffusor is effectively absorbed. Absorption of rear radiation prevents acoustic short circuiting, improves the frequency characteristics of the system, and increases output at low frequencies.

The production of a large amount of acoustical power at low frequencies also helps cophasal actuation of the loudspeakers. High frequencies were reproduced by two 1A17 horn-type dynamic heads with acoustic lenses.

As the horn loudspeakers have an acute directional diagram, reflecting plates were placed at the mouth of the horn in such a way that sound emergy in a given space is distributed evenly.

In those cases when the effect on the organism of a specific sound must be studied, it is permissible to use a tape recording. The most popular tape recorders recommended for these purposes are the MAG-8, MAG-59, "Melodiya," and "Reporter-3." Therefore, in the second soundproofed chamber, magnetic tape recordings of noises were used along with artificially-generated noise.

To reproduce noise for a long period of time, a part about 2 m long was removed from the recording, spliced into a ring and reproduced by a simple additional device on the tape recorder. This device consists of two arms with a freely rotating roller attached singly to each one. These rollers provide tension for the ring of ferromagnetic tape with the noise recording. The tape is drawn out by a rotating rubber-covered roller attached to the top shaft. /61

To reduce the reproduction of interference at the point of juncture on the tape ring, splices and repairs to the "joint" were made with "Scotch" brand tape. The signal from the tape recorder was fed to two UM-50 power amplifiers ending at a 2-band acoustic unit.

Physiological research equipment was also mounted in the chamber: to study the central nervous system (electroencephalograph, chronoreflexometer, an instrument to determine the critical frequency of acoustic flashes), the auditory analysor (tonal and vocal audiometers), the cardio-vascular system (mechanocardiograph, pulsotachometer, electrocardiograph) and the muscle system (electromyograph). Control panels are outside the chamber. There is a bilateral connection between the experimenter and the subject inside the chamber — light and sound.

The creation of such acoustic complexes will make possible detailed studies of the effect of various parameters of stable and impulse noise on the functional state of the human organism and of animals.

The Selection and Unification of Physiological Research Methods in Studying the Effect of Noise on the Organism

There are basically three directions in the study of the effect of noise on the organism: experimental, hygienic and clinical-industrial; these divisions are purely arbitrary, for in essence it is one general direction. In this respect, selecting a research method is necessary and important.

Of course, considering noise as a factor causing noise sickness obliges authors to approach the evaluation of damage to the organism from the position of I. P. Pavlov, N. Ye. Vvedenskiy and A. A. Ukhtomskiy. P. P. Pavlov thus indicated the necessity of studying the interaction, interconnection, and interference of

organs or functions ultimately leading to a correct concept of the organism as a single inseparable whole and in its interconnection with the environment. I. P. Pavlov also was a firm believer "that our understanding of the whole is based on a knowledge of the parts."

In this connection, a complex approach to the evaluation of the state of the organism and its functions under the effect of noise is required of doctors and physiologists. This can be attained by proper direction of experimen[illegible]d the necessary series of methodological processes. In this section we sha[illegible]riefly discuss the most common human physiological research techniques, and several evidences of modeling on animals to discover intimate processes which occur in the organism under the effect of noise. /62

Study of the central nervous system. The effect of intensive sound stimuli on higher nervous activity was studied in the laboratory of I. P. Pavlov, where it was established that sound signals of excessive force can cause overstress of the stimulus process and "breakdown" — impairment of higher nervous activity. The research was subsequently continued by many physiologists.

As is known, at the first stage of studying higher nervous activity a number of techniques were developed — the motor-food and saliva technique of Krasnogorskiy, the motor-defense technique of Bekhterev, the vasculo-motor platysmographic technique of Tsitovich, which made it possible to study human conditioned reflex reactions based on unconditioned reflexes.

However, specific characteristics of higher nervous activity in man required techniques which would permit the study of willed, conscious reactions, especially characteristic of man, formed with the aid of voice activity, i.e., by the use of conditioned connections accumulated in the course of an individual life betweer words and corresponding actions.

At the present time in the study of higher nervous activity in man, there is a wide use of two basic variants of the voice-motor technique: the first — with the formation of motor conditioned reflexes on the basis of preliminary voice instructions (Ivanov-Smolenskiy method); the second — with the formation of motor conditioned reflexes on a basis of vocal confirmation (Protopopov method). Each

of these variants has positive aspects and inadequacies. In the voice motor method of Ivanov-Smolenskiy, the positive aspects, as indicated by the author, are that it permits observation of the rate of formation of time connections.

One of the disadvantages of this method is that in a large number of adult subjects with normal higher nervous activity, no time connection is obtained on /63
the basis of confirmation, and to form a time connection, it is ultimately necessary to give the subject verbal instructions.

The necessity of preliminary instruction was also emphasized by I. P. Pavlov, indicating that "one will guess what he should do and another will be in a quandary," and further: "By not giving warning, in my opinion, you directly contaminate the test" (I. P. Pavlov, 1947).

The Ivanov-Smolenskiy method is only adequate for young children, in whom the time connection is not yet based on verbal instruction, but is based on vocal confirmation. For adult subjects the voice-motor method with preliminary verbal instruction is more adequate, as here speech is used more completely and naturally, leaving no room for absurdity and misunderstanding.

In studying conditioned reflexes in man, many authors are only interested in analyzing its latent period. Excluding the effector response and its intensity and other characteristics, as noted by Z. L. Sinkevich (1963), the researchers intolerably narrow the possibilities of their data and thereby reduce their achievements.

A series of reflexometers was used to measure the latent period of the conditioned reflex; these consist of interconnected communication channels with a panel for the researcher, equipped with a time measuring unit, engaged at any signal of the experimenter and disengaged at the action of the subject on the transmitter corresponding to the pertinent reaction. Many reflexometers also measure the magnitude of the reaction, for example, the amplitude of movement of the reacting extremity or the intensity of pressure on the transmitter.

Portable electro-mechanical timers have been widely used as chronoreflexometers. The chronoreflexometer developed at the Leningrad Medical Institute of Health and Hygiene makes it possible to register the time of the latent period of the motor reaction in milliseconds, as well as the force of pressure of the subject on the transmitter in relative units (milliwatts).

A chronoscope makes it possible to produce conditioned stimuli only at that moment when the moving needle passes the zero position. In a single moment the arrow of the electronic dynamometer, depending on the force of pressure of the operating key, deviates a certain number of milliwatts.

When the conditioned stimuli are supplied by the experimenter, the subject, /64
in whom a conditioned reflex has been previously developed presses the key plate immediately after they are perceived.

In response to the pressure of the key, the arrow moving along the chronoscope scale is instantly arrested, fixing the time elapsing between the start of the conditioned stimulus and the reaction of the subject, and the force of pressure is noted on the dynamometer. Each subject received preliminary instruction before the start of the first experiment. In cases when the studies were conducted in experimental conditions, the subject was placed in a soundproof chamber; on the wall in front of him a block of instruments was installed with a key mounted on it, and sound and light stimuli. The index finger of the right hand was placed on the key plate. The experimenter was outside the chamber beside the control panel (Figures 25a, b). In those cases when the studies are conducted in industrial conditions, it is necessary to select a quiet place with minimum extraneous stimuli. The subject must be situated so he cannot see the manipulations of the researcher.

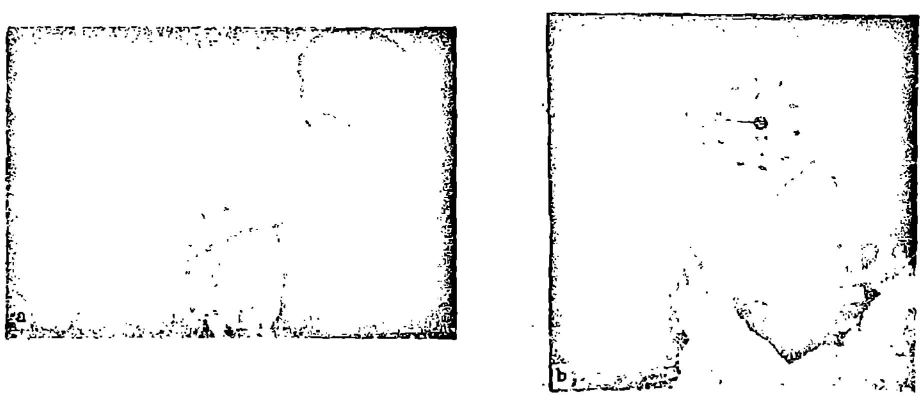


Figure 25. Study of the functional state of the central nervous system using reflexometry: a - position of the subject at the instrument; b - recording part of the instrument.

After verbal instruction: "As soon as you see or hear the signal, immediately press the key plate," and a number of preliminary studies, the subject is informed of the start of the experiment by the command "Ready!" In 2 - 3 seconds after the instrument is actuated, a signal is given. Upon perception of the signal (a strong and weak light) the subject immediately presses the key plate, stopping the arrow of the chronoscope by this movement and the deflections of the electronic dynamometer pointer. Signals are usually given with intervals of 10, 15, 20, 30 and 50 seconds.

The first 5 - 8 sets, which were presented to each subject for developing the conditioned reflex, are not included in data analysis.

With the use of this method, many Soviet and foreign authors obtain interesting data; however, a number of circumstances must be taken into consideration (Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, A. V. Kadyskin, 1967). Particularly, despite the large number of various kinds of reflexometers used by researchers to determine the intensity and time of the latent period of visual and auditory motor reactions, parameters such as the intensity of light stimuli, the level of intensity and the frequency composition of sound signals, as well as experimental conditions still remain unstandardized. At the same time, all these factors have a considerable effect on the reaction time. The experimental research of Medeiros and his associates (1965) showed that reaction time is affected by illumination levels and sound intensities, but the most significant characteristic is the intensity of the /65
stimulus, which is directly dependent on reaction time. Costa and his associates (1965) have established that changing the intensity of the signal affects the mechanical delay of the reaction time.

The time dependence of the reaction on the intensity of the stimulus has been studied by many authors and has been definitely established. All authors agree that the maximum reaction time is observed with near-threshold stimuli; as the /66
intensity is increased, the latent period is sharply reduced, and with certain moderate intensities of stimulation the reaction time reaches its minimum and subsequently barely changes.

The research of Hall and Kries (1879), Kasther, Wirh, Smith et al., (1952) also showed that the location of the signals and their distance from a central line must be considered in determining reaction time to light. According to the data of

Kobrick (1965), reaction time increases significantly wher the signals are located more than 30° above a horizontal line with side spacing 55° from center. When the signals are placed along the horizontal line of sight (even on the periphery), no essential shifts are observed in reaction time. In the works of Bevan (1965), it was also shown that the reaction time is less with constant than with varied intervals. The differences in the time reaction between groups with constant and those with varying intervals increased in relation to their length.

On the basis of published data, as well as numerous experiments conducted at the Department of Occupational Medicine of the LSGMI, a unified method of studying acoustic and visual motor reactions has been recommended (Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, A. V. Kadyskin, 1967). Light signals must be placed level with the horizontal line of sight; the intensity of a weak light signal is 2 lx, and that of a strong light signal — 30 lx. In using a sound stimulus, as we suggest, both the level of intensity and the frequency composition of the sound signal must be taken into consideration. We find it possible to use as a test a pure tone of 1000 Hz with a level of intensity of 80 dB for a weak stimulus and 90 dB for a strong sound stimulus. We must also note that surrounding noise must not exceed 30 dB. When conducting the study under noisy conditions exceeding these parameters, its level of intensity must be recorded.

Study of concentration of attention. In studying the effect of noise on the central nervous system, authors attach great importance to attention. As is known, attention was the object of study even in the XIX century. The first experimental research in the area of attention was conducted in the laboratory of V. Vund (1912). Subsequently, Soviet and foreign authors have conducted a large number of experiments dealing with the scientific basis of attention and the effect of sound stimuli on attention.

Among the basic kinds of willed attention, its concentration pertains to a number of complex processes. We must also note that, from a practical point of view, a given kind of attention is related to a number of very important processes, as it is one of the basic conditions of prolonged human activity in physical and mental work. /67

In studying changes in concentration of attention under the effect of noise of various parameters, the majority of researchers use the "crossing-out" method. Research work in this country most often makes use of the proof lists of Anfimov, edited by V. V. Rozenblat and Yu. V. Kalinin. This method consists of giving the subject a list of items or the text from a book and instructing him to read over these symbols for a certain length of time and cross out those which were shown him before the start of the study. To avoid becoming accustomed to the same symbols, the setting must be changed. The degree of accuracy and productivity of attention are determined by the number of correctly crossed out symbols.

A. Z. Marinyako (1964) described a simple and available method for attention. The essence of this method is that a number on a clock dial is called to the subject, and as it is passed by the second hand he must make a mark with his finger. Premature reactions are noted by a - sign (minus), and late reactions by a + sign (plus).

Study of the auditory analysor. An important aspect of studying the effect of noise on the auditory analysor is the qualitative change in hearing (audibility) and the establishment of measurement units on a continuous scale of intensity and frequency. One of the most common methods of evaluating the results of noise influence is tonal audiometry.

Audiometric measurements concern signs of objective values; reactions of the human subject are a reflection of subjective feelings. To find a common language for physicists and psychologists, it was necessary to establish the relation between objective and subjective values. The basis of audiometric measurements was the Weber-Fechner law which concerns all kinds of stimuli, not merely acoustic. As is known, according to this law, perception of a stimulus increases in geometrical progression. In other words, the perception of a stimulus is a logarithm of the stimulus.

The most important range of frequencies for characteristics of auditory sensitivity was studied — from 100 to 6000 - 8000 Hz.

To study hearing with separate tones (tonal audiometry) one must have sources of sounds which will produce pure tones in a wide range of audible frequencies of any strength. At the present time tuning forks, as well as electric sound generators and audiometers, are used for this purpose. /68

It is recommended that all audiometric research be conducted in a quiet place, preferably in a soundproof chamber. The presence of surrounding noises, as with the study of visual- and audio-motor reactions, can significantly distort the data. Acoustic insulation to a level of 20 - 30 dB is completely satisfactory for physiological-hygienic and clinical research. We must note that it is usually not recommended to make higher soundproofing demands, as conditions approximating absolute quiet are far from physiological and they certainly have an unfavorable effect on the examinee and create conditions for the possible pronounced effect of the natural sounds of the organism, primarily the sound of pulse and respiration.

In experimental and clinical conditions, it is desirable to conduct audiometry in rooms made of two parts. The audiometric equipment and the researcher occupy the first part of the room, and in the second, insulated part is the acustic-examinee wearing earphones. In cases when it is difficult to select a room made of two parts, it is necessary to use a room with the lowest levels of surrounding noise. The examinee must be seated so that he cannot see the manipulations of the examiner. He reports the perception or nonperception of the signal with the aid of a light signal by pushing a button on the microphone connection or by raising and lowering his hand. The subject is allowed to hear, in preliminary testing, several tones, while he does not know what is expected of him. The study is first conducted at a frequency of 1000 Hz, then at 2000, 3000, 4000, 6000 and 8000 Hz, then is again verified at 1000 Hz, and, finally, auditory sensitivity at frequencies of 500, 250 and 125 Hz is determined.

One must try not to prolong the time of the studies, as increasing exposure can fatigue the auditory analysor. At the same time, foreign literature includes indications that, to shorten the time of the studies, it is possible to conduct tonal audiometry on only one frequency. It is difficult to agree with this, as, for example, in the research of S. V. Alekseyev (1964, 1968) it was shown that in the effect of separate octave bands of noise, the greatest reduction in hearing is observed within the operative band, as well as in the half-octave above. Thus, /69

the strongest effect on the voice frequency range should be that of noise whose greatest amount of energy is located in the low and medium frequency components. Although losses of hearing at frequencies over 2000 Hz do not disturb voice perception, they should be taken into consideration, as the shift in thresholds at frequencies over 2000 Hz is usually more pronounced and they can be a certain criterion in determining the state of auditory sensitivity. We must also consider the fact that under industrial conditions various kinds of sound signals are often used whose spectrum primarily consists of high-frequency components, and failure to reduce hearing at high frequencies can lead to industrial traumatism.

The level of intensity perception by the audiometer must be periodically controlled and adjusted at least every three months. As is known, the simplest means of control is determining threshold curves in 5 - 10 young people with normal thresholds of audibility. We must also note that a tonal audiometer, like any electronic instrument, must be checked every day in special units, and in case of inaccuracy independent repair is not recommended, but its independent parts should be exchanged.

In particular, the problem of maintaining audiometric values in an unchanged condition is closely connected with that of earphones, as earphones are the most defective part of audiometers. The earphone consists of a special cushion which creates a certain volume of air between it and the ear drum. The acoustical load provided by this volume enters into the initial calibration; therefore, the cushion should not be changed without special reasons. Different padding in the same earphone can change the level of intensity by 6 - 8 dB or more. The means of mounting the earphones is also important; they must not cause pressure on the external ear, as this can cause pain in a long test; pressure on the external ear can also intensify bone conductance, which can reflect on the results of the study. There are also data indicating that pressure can lead to collapse of the external acoustic meatus, which can also be a cause of inaccurate results of audiometric study. The earphone and the bone vibrator must be positioned with special mountings, as when the earphones are held to the ear with the hand, muscular tremor is transmitted which usually masks low frequencies and the ear is subjected to extraneous sounds. /70

For massive research of hearing, some authors often use tonal audiometry in a free sound field. In this case, we must caution against possible inaccuracies which can develop during the study, as levels of sound pressure largely depend on the direction of sound toward the external acoustic meatus.

Voice audiometry. Pure tones used in tonal audiometry are a good laboratory test, which is applicable to the study of hearing. But the human auditory analysor is more capable of perceiving complex sounds, usually in voices and higher frequencies in nature.

Continuous communication between hearing, voice and muscles is necessary for the complete development of man. Voice perception is not only a physiological process, but a psychological, cortical process, and using a tonal audiometer there is no possibility of recording and measuring all the elements of this process.

As is known, the frequency band between 400 and 2500 Hz is most important in voice discrimination. It is natural to expect that hearing reduction for pure tones in this frequency band has the greatest effect on change in voice perception. B. V. Bogdanov (1959), O. V. Solovey (1965) and others, have in fact, shown the presence of a direct dependence between these two effects. However, various cases of sickness are known clinically in which considerable discrepancies are discovered between a loss of hearing for pure tones and for speech. There are cases when voice perception is significantly more disturbed than the perception of pure tones.

Voice study of the auditory function is one of the oldest means of research. Methods universally used for this purpose until recently consisted of finding the minimum distance between the mouth of the speaker and the ear of the subject which is necessary for correct sound perception of whispered or conversational speech. Determination of the distance served as a certain standard of voice sounds necessary for its distinction. The main fault of such a study was the impossibility of standardizing force and quality of sounds, as a result of which the disparity in studies could reach 10 - 20 dB.

Taking into consideration the disadvantages of studying conversational, whispered speech, G. I. Grinberg and R. A. Zasosov (1952) suggested a voice audiometer. The advantages of this instrument over using frequency and conversational /71

speech are the uniformity of text and diction, regulation and recording of the level of intensity of transmitted sound recording, and also that loss of hearing is determined in comparative values — decibels (dB). It consists of conversational speech or single words, recorded on magnetic tape or a record, transmitted without distortion on a dynamic telephone attached to the ear of the subject. The force with which the word is transmitted is here regulated by an attenuator.

In this country, for voice audiometry we use the six tables of T. I. Grinberg and L. R. Zinder (1956), each of which consists of thirty words. The results of voice audiometry are recorded in the form of growth curves of intelligibility of speech in special blanks where the level of sound intensity is plotted along the abscissa axis, and the intelligibility of speech in percentages — along the ordinate axis.

In physiological-hygienic and clinical studies, the following points are usually determined to obtain the curve of intelligibility: the threshold of sound detection, and speech sounds, the threshold of detection of 50 and 100% of audible words. Normally with a level of intensity of 30 dB, intelligibility of speech is 50%; with an intensity of 40 dB, it is 80%; when the intensity of transmitted words reaches 50 dB, intelligibility of speech reaches 100%.

Mass examinations can be limited to determining the threshold of 50% voice intelligibility. The results of this study are plotted on a tonal audiogram blank in the form of a double shaded line in the frequency range from 256 to 4096 Hz. Loss of hearing is determined in this case as the difference on this scale between the threshold of 50% voice intelligibility of the subject and the threshold of 50% intelligibility of a person with normal hearing (Figures 26a, b) (S. Z. Romm, 1966).

Discretometry. The use of tonal and voice audiometry methods in studying the effect of noise on the auditory analysor is very important. However, the use of this method does not permit adequate evaluation of the functional state of the auditory anayscr. As is known, any analysor consists of numerous functional units, distinguished by varying degrees of excitability. The range of stimulation characterizes the so-called functional mobility of nerve processes of a particular analysor.

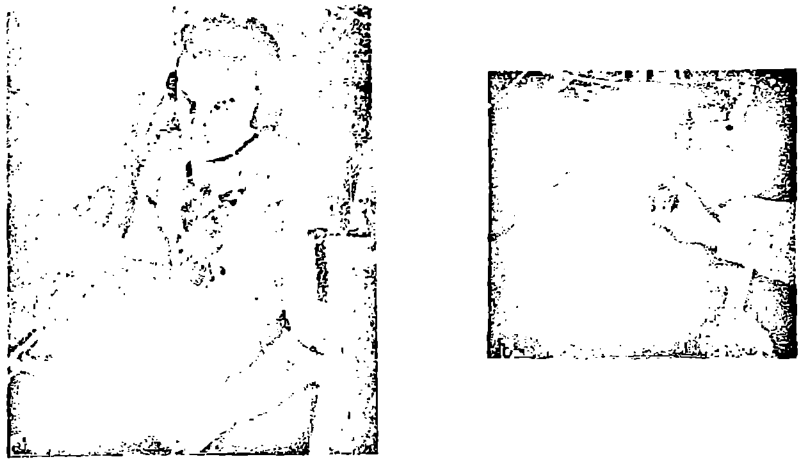


Figure 26. Audiometric study of hearing: a - subject in soundproof chamber in a study of air conductance; b - recording the subject's responses.

The research of A. I. Bronshteyn (1936), P. O. Makarov (1936), S. N. Gol'dburt (1964) and others revealed a high functional mobility of the auditory analysor; any change in the functional state of the nervous system affects the value of the critical discrete interval (discontinuity). /72

The most acceptable method in physiological-hygienic research to study the mobility of basic nerve processes in the auditory analysor is determining the critical frequency of a discontinuous noise stimulus (sound bursts). A type VZ-58 modified discontinuous noise generator can be used for the study. This determines the critical frequency of "sound bursts," i.e., the maximum number of intervals per second, which is still perceived by the subject as discontinuous noise. With further increase in the frequency of the bursts, the intervals merge and the noise is perceived as continuous noise.

The discontinuous noise generator is a block in which a white noise generator and an interrupter are combined. Noise is interrupted by a circuit composed of a multivibrator and a type RR-7 relay. Also specified in the system are amplifiers of the level of continuous noise and discontinuous noise, "sound bursts." The

instrument has three scales which determine the critical frequency of the discontinuous noise stimulus at absolute values from 2.4 to 360 interruptions per second; and a generator of continuous and discontinuous noise to dynamic telephones. There are two jacks on the instrument: one — to connect the control telephone, through which the subject hears the white noise, and the second — for the "sound burst" telephone to which discontinuous noise is fed. /73

In studying the mobility of nerve processes in the auditory analysor of the subject, he first becomes familiar with discontinuous "white" noise and with continuous noise, for example, at frequencies of 170 - 190 pps/sec. Then, noise with widely spaced interruptions is presented (8 - 10 pps/sec). When there is a correct response, the frequency of interruptions is increased, consistently monitoring the responses of the subject. Subsequently, the frequency of interruptions is increased until the subject registers the blending of separate "sound bursts" in one uninterrupted, continuous noise. This study is repeated 3 - 4 times with each subject, and in comparing the results the greatest frequency of sound bursts, which are still differentiated as individual variations of sound, usually is considered as the critical frequency of "sound bursts."

Study of the cardio-vascular system. Tacho-oscillography. At the present time, in studying the harmful effect of noise on the organism, specialists are widely studying the functional state of the cardio-vascular system. As is known, the functional state of this system is characterized by changes in hemodynamic factors. The most important of these are: systolic and minute volume of blood, arterial pressure, pulse rate, vessel tone, peripheral resistance, volume of circulating blood, rate of blood circulation, venous pressure, bleeding rate, capillary hemorrhage.

Arterial blood measurements and pulse rate are most widely used by the authors in studying the effect of noise on the cardio-vascular system in experimental and industrial research.

Arterial pressure is the resultant interaction of numerous hemodynamic factors. The most important of these are: a) the amount of blood in the vascular system per unit of time; b) the amount of blood leakage through the precapillary channel; c) capacity of vascular walls; d) compressive stress of arterial vascular walls.

As is known, minimal pressure, lateral or true; systolic pressure; mean pressure and maximum or final, systolic pressure can be differentiated.

All indirect methods of studying arterial pressure in man are based on determining the reaction which must be created in the cuff to cause certain disturbances in the movement of blood in the artery of the arm.

In some cases, the change in the amount and shape of oscillations — the oscilliatory method — is used as an indicator, and in others — the appearance of sound variations.

In hygiene practice in studying the effect of noise on the functional state of the cardio-vascular system, the acoustic means of determining arterial pressure is most widely used because it is the simplest. /74

In measuring pressure, according to Korotkov, the development of sound largely depends on the functional state of the vascular wall and does not change only with a change in pressure. It becomes clear that in studying dynamic change in blood pressure data obtained by acoustic means must be treated with caution.

The oscillography method is used to determine mean pressure. We must note that instruments for recording the oscillogram, on the basis of which the level of average hemodynamic pressure can be determined, differ by their great inertia. Typical oscillograph curves are obtained only in 30% of the measurements. In 70%, it is difficult to establish not only the amount of mean pressure, but even the level of minimum and maximum pressure, as the transition of the oscillations from small to large occurs gradually (N. N. Savitskiy, 1963).

In physiological-hygiene and clinical research, the most acceptable is the tacho-oscillographic method, suggested by N. N. Savitskiy which essentially differs from previously listed methods in that, instead of optically recording changes in the volume of the vessel under the cuff, the rate of volume changes is noted.

The differential curve obtained in this way gives the characteristic changes in its lower diastolic section; therefore, in reading the curve the changes in the height of the oscillations are not considered, as was suggested by Mare, but the

deformation of the lower section of the oscillogram, which accurately determines all four values characterizing arterial pressure. This method removes all inaccuracies in determining mean pressure related to the use of other methods based on the principle of Mare. The tacho-oscillographic method of studying the functional state of the cardio-vascular system under the effect of various parameters of noise in industrial and experimental conditions allowed the coworkers of the Department of Occupational Hygiene of the LSGMI*to determine indirectly in man the amount of true systolic (lateral) pressure, and therefore, the true amount of pulse amplitude and the amount of the hemodynamic beat, or beat pressure.

Pulsotachometry. In hygienic practice, pulse rate is measured to obtain the characteristics of changes in the functional state of the cardio-vascular system under the effect of various industrial factors. At the present time, various types /75
of pulsotachometers are being increasingly used.

Determining pulse rate with a pulsotachometer is based on the principle of measuring residual voltage in a capacitor charged to a certain voltage and discharged during a time interval, i.e., the lower the pulse rate, the less voltage in the capacitor at the end of the discharge. Because of this, the scale of the voltmeter, measuring residual voltage, can be calibrated directly in pulse rate units (beats per minute).

This method allows dynamic observation of the pulse rate for any length of time, both in clinical as well as industrial and experimental conditions.

A method of studying the central nervous system in animals. Scientific developments indicate that the productivity of research is determined, on the one hand, by proper formulation of the problem and aims of the study, and on the other — by the methodological process of conducting the experiment. We know of many examples when the research method played the determining role in developing a certain problem.

The use of electrophysiological research methods was a new stage in the development of medical science. The example of the scientific work of I. M. Sechenov, N. Ye. Vvedenskiy, A. A. Ukhtomskiy, and I. P. Pavlov shows conclusively that the method of study played a decisive role in understanding the very complex aspects of the vital activities of organisms.

*Translator's Note: LSGMI = Leningrad Sanitation and Hygiene Medical Institute.

It will not be an exaggeration to say that electroencephalography, the purpose of which is to study the electrical activity of the brain, has now become one of the basic, and in many cases still the only means of studying various aspects of the activity of the central nervous system of animals and man. The electroencephalographic method helps to reveal the role and importance of various brain formations, and to discover increasingly newer regularities in its functional organization and activity.

However, electroencephalographic methods which can record directly the reaction of the central nervous system in studying the results of noise have until recently obviously not been used enough. This can be explained by the following: first of all, the electroencephalographic method of research was only conceived in the 1930's when noise had not yet assumed the character of an urgent problem requiring solution; secondly, until recently, studies of its effect on the organism in the majority of cases were aimed at finding its effects on the function of the auditory analysor, and only recently have there been studies of the inadequate effect on /76
the organism.

Therefore, until now the question of the effect of noise on various sections of the central nervous system has remained open.

Of great importance in the effect of noise are the electrophysiological characteristics of various zones of the cerebral cortex where important analytical and synthetical processes occur which serve as the basis of higher nervous activity (I. P. Pavlov, 1926). However, even I. P. Pavlov pointed out the differences between functional properties of nerve structures of the cortical and subcortical level; he emphasized that "from the physiological point of view, subcortical centers are characterized by intertia in relation to stimulation as well as inhibitory processes." This characteristic of subcortical centers, and the "stability of nerve processes causes the subcortex to tone the cerebral cortex," appear to be the source of its power. The discovery of differences in the properties of nerve processes in the cortex and subcortex allowed I. P. Pavlov to advance the theory of functional cortical-subcortical relations as the basis of the integral activity of the brain. However, the study of the physiological mechanisms of the activity of subcortical formations still remains one of the pressing problems in the physiology of the central nervous system. This is why the study of the functional

characteristics of various subcortical nerve formations in response to the effect of a sound stimulus, having such a wide extent, is of such obvious interest.

Of invaluable service in this respect is the method of studying the bioelectric activity of various stages of the central nervous system by implanting electrodes in a chronic experiment.

The materialistic theory of I. P. Pavlov about higher nervous activity convinces us that chronic experiments are the only proper method. It must be emphasized that only by studies which are conducted under chronic conditions can data be obtained which reflect the true functional interrelations which have been accumulated in the organism in certain circumstances. The advantage of chronic experiments is the possibility of studying a physiological phenomenon in a practically intact organism, to examine a given phenomenon in dynamics, to reproduce the process, and, finally, to study true functional phenomena in those parameters which exist in nature.

We know that researchers were interested in subcortical formations even in the XVIII century; however, this problem still maintains its timeliness. One of the basic reasons for this is the level of methodological processes of study used in the various periods of the development of electrophysiology. Therefore, the great importance of chronic experimental means for studying the activity of different stages of the central nervous system under the influence of various stimuli, including noise, requires no additional proof. /77

The most pronounced use of chronic methods to study central physiological mechanisms in the activity of the brain is the utilization of electrode implantation. Electrode implantation as a means to study bioelectric reactions of the central nervous system under conditions of relatively free behavior of animals was first suggested in this country by A. B. Kogan (1936). It was he who developed the necessary technical and methodological principles for combining various applied stimuli of nerve structures and recording biopotentials from them in chronic experimental conditions (A. B. Kogan, 1949). By now the use of implanted electrodes is common here and abroad. Many works of various authors have appeared which generalize experience accumulated in this direction (A. B. Kogan, 1949; "Electrical stimulation of the Brain," Texas Press, 1961; Ya. Buresh, M. Petran' and I. Zakhar, 1962; Yu. G. Kratin, N. P. Bekhterev, V. I. Gusel'nikova, V. A. Kozhevnikov, V. T. Senichenkov, V. V. Usov, 1963; R. A. Durinyan, 1965; and others).

N. A. Rozhanskiy (N. A. Rozhanskiy and T. G. Urmancheyeva, 1955) in particular, has written that "subcortical structures must be studied as a complex, using the method of chronic implantation of electrodes, studying the properties of the sub-electrode region by means of applying various stimuli, considering location, and what is especially important, studying electrograms under various influences or induced conditions" (quoted by F. P. Vedyaev, 1965).

On the basis of the above, in modern research one of the primary methodological processes is studying bioelectric activity of various sections of the brain by implanting electrodes, as well as several autonomic functions in conditions of relatively free behavior of animals in a chronic experiment.

Research is most often conducted on non-narcotized rabbits (A. V. Kaiyskin, 1967). The selection of rabbits as the experimental object was motivated by: first, adult rabbits have standard sizes and shape of skull and this insures accurate entrance of the electrodes into the necessary structures, and secondly, /78
the majority of experimental electrophysiological brain research described in the literature, was conducted on rabbits, which makes it possible to compare our data with published material.

In connection with the fact that stereotaxic atlases are compiled for average sizes of animal brains, rabbits selected for the experiment had skull sizes close to the average. The necessity for this is indicated by R. M. Meshcherskiy (1961). The most successful experiments, in which accuracy of implantation was greatest, took place when rabbits weighing 3 kg were selected for the test.

For leading off biopotentials in deep-seated structures of the brain, we used metallic manganin and Nichrome electrodes 0.6 - 0.7 mm in diameter. Insulating material for the electrodes was an alcohol solution of bakelite lacquer, resistant to biological effects. Only the tip of the discharge electrode remained uninsulated. The potentials developing in the cerebral cortex were led off with the help of cortical electrodes made of stainless steel.

The operation of implanting the electrodes for the chronic tests was conducted under morphine-aminazin narcosis with a stereotaxic instrument according to the atlas of Ye. Fifkova and G. Marshall (1962) in relatively sterile conditions.

After preliminary preparation of the operating field, the head of the animal was fastened in a head support. The skin was smeared with iodine and 70% alcohol. The surgical instrument was sterilized by the usual means. Then the skin was slit and the skull exposed, the periosteum was removed. Trephination sections were found and noted on the surface of the skull in relation to dead center. In the marked sections of the skull, fastened in the stereotaxic instrument, holes were drilled with a hand trephine. Previously disinfected electrodes were attached to the support. Then the coordinates of trephined holes were again verified and having carefully dried the bone, the electrode, fastened to the electrode support, was introduced with a DK-3 instrument.

Cortical electrodes were implanted as follows: a needle attached to a special holder, was mounted by the blows of a small hammer in the corresponding projection zone of the rabbit's cerebral cortex.

Subcortical electrodes were implanted in the specific nucleus of the thalamus, the ventral, medial, and reticular nuclei of the thalamus, as well as in the reticular formation of the mesencephalon and the pons varolii. Cortical electrodes were introduced into the auditory, sensory-motor and optic regions of the cerebral cortex.

Selection of structures for bioelectrical activity research was motivated by various reasons. Recording the biopotentials of the cortical areas, where the most important analytical-synthetical activity takes place, made it possible to evaluate the dynamics of basic nerve processes in these zones as well as study the reaction of the central part of the auditory analysor to prolonged noise. /79

On the basis of morphological data, it can be asserted that the thalamus based on its construction perceives afferent impulsation from all receptor-analysor systems. As the medial and reticular nuclei are formations of the thalamus, which according to present concepts is related to the diffuse projection thalamic system (P. K. Anokhin, 1958, 1969; A. Brondal, 1960; Megun, 1955) and along with the reticular formation of the brain stem has an activating effect on the cortex, there is great interest in finding the "personal interests" of these structures in response to a noise stimulus.

In the entire complex of nonspecific nuclei, the reticular nucleus is especially interesting. It has direct connections with the cortex and, in practice, is connected with all brain structures (R. A. Durinyan, 1965). Of special interest is recording biopotentials of the lateral nucleus of the thalamus, as this nucleus is a nonspecific part of the auditory tract, the study of the functional state of which is of undoubted interest in sound stimulation.

All implanted electrodes were immobilized by a medical styracrylic. We know that for qualitative recording of biopotentials, reliable electric contact must be created between the electrodes implanted in various brain structures and the imput of the electroencephalograph amplifier. Many varied methods of implanting and attaching electrodes have been developed for recording the EEGs of animals. However, this often requires the use of special electrode blocks or immobilization of the animals, which is undesirable for conducting chronic experiments. Therefore, we used ordinary seven- and nine-pin tube sockets, the bases of which were attached by styracrylic on the skull of the rabbits. All implanted cortical and subcortical electrodes as well as indifferent electrodes located along the center line of the skull on the nose bones of the rabbit, were soldered to the metallic terminals of the socket. Then it was finally attached by medical styracrylic. Stable electrical contact between the implanted electrodes and the input of the EEG amplifier was reached so that during the experiment the plug with the cord of conductors, leading to the input of the electroencephalograph, was closely connected with the socket (Figure 27). Aligning plugs were arranged on the panel to correspond to the sol- /80
dered electrodes. The input system of the electroencephalograph was attached to the wall of a screened cage.

Figure 27. Rabbit during the experiment.

The animal tests began a week after the operation so that stimulation and edema of the brain structures involved in the operation were reduced to a minimum.

Means of leading off bioelectric potentials of the brain. The potential lead from all the structures studied was monopolar. This is due to the fact that at present the majority of authors recognize the advisability of monopolar leads, which record the difference of potentials between any active and indifferent electrodes. In bipolar leads the algebraic sum of the original monopolar leads is recorded. Thus, bipolar tracing does not give the true location of centers of stimulation or the form, amplitude or changes of induced potentials. Therefore, in studying induced potentials, the most adequate means of recording, providing both sufficient localizability and accurate reproduction of the form of electric brain responses, is a monopolar lead (R. M. Meshcherskiy, 1965).

Methods of studying the dynamics of basic nerve processes under the influence of noise with the aid of functional tests. The functional mobility of the nerve formations of the brain in question under conditions of prolonged noise was determined by applying rhythmical light stimuli from a photostimulator with stimulus frequency from 0.5 to 30 Hz. The distance from the light source to the animal was 250 mm, energy of the flashes — 0.3 joule. Photostimulation was applied before the noise, during the experiment and after the noise effect, which makes it possible to judge changes in the functional lability of brain structures in the dynamics of the experiment. /81

The areas of the brain in which changes develop in response to noise were defined more precisely by using drugs selected for their effect on certain zones of the brain. In accordance with present concepts of biologically active substances which react with specific biochemical systems in cell synapses, we used drugs which reinforce and depress developing inhibitory and stimulating processes. We used an adrenolytic — aminazine, an adrenomimetic — phenamine, a cholinolytic — amyzil and an anticholinesterase preparation — nivaline.

During the experiment, the animals were placed in a screened cage 1000 x 500 x 500 mm in size, in conditions of relatively free behavior in a specially constructed soundproof chamber. All noise-reproducing, noise-analyzing, and physiological equipment was in an adjoining room. The chamber was remotely controlled. The behavior of the animals during the experiment was observed through a special viewing window.

Methods of checking the insertion of electrodes. After the experiments were finished, the animals were killed, and the location of implanted electrodes was checked on serial brain sections, stained by Nissl's method. The essence of histological control is that the electrode trace was determined in corresponding frontal brain sections as well as the location of the tip of the electrode. If the frontal section is strictly parallel to the electrode channel, its intermediate positions are also quite accurately determined. The sections were miscroscoped and photographed. The location of the electrodes was compared with frontal sections of the rabbit's brain.

Special attention must be given to the quality of the inflicted noise stimuli. On a vast biological scale, the problem of stimulus quality has been developed in the works of D. A. Biryukov (1960), F. P. Vedyaev (1965) and others.

In fact, if we do not attach special importance to the physical characteristics of inflicted noise stimuli, we can arrive at essentially different conclusions about /82 response reaction of brain structures. However, published works often lack accurate physical characteristics, while, as has been proven (Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, A. V. Kadyskin, 1967), even slight changes in the quality of the inflicted noise stimulus will lead to essentially different reactions of the organism. Therefore, the physical characteristics of noise must be under constant control so parameters necessary for the purpose of the experiment are strictly maintained.

The data obtained as a result of the experiments were subjected to statistical analysis according to the variation statistics method. Mean values of the electrical variations under study (frequency, amplitude) were calculated, as well as mean error, root mean square deviation, Student criterion and the correlation coefficient. Test results were considered reliable if the Student criterion was not less than 1.98, which corresponded to a significance level of $P \leq 0.05$.

Methods of studying several autonomic reactions in animals under the effect of noise. Along with the study of the reaction of the central nervous system to the effect of a noise stimulus, there is also interest in changes which develop in cardiac activity and in the respiratory system, depending on the parameters of the noise, and comparing them with responses of the central nervous system. This was necessary in order to find the degree of involvement in the response reaction of

vital centers of the autonomic nervous system. Electrocardiogram and pneumogram tracings were made for this purpose.

The electrocardiogram was recorded with steel needle electrodes. The tracing was made before the noise started, against a background of the noise effect (after 0.5, 1.5 and 3 hours) as well as in the after-effects period. These recordings of the bioelectric activity of heart muscle determined the value of the R-R and Q-T intervals. Then, according to the tables of G. A. Antropov (1965), compiled for various EKG indices for rabbits, it is possible to find the heart beat rate per minute, systolic indices (actual and normal) as well as the normal length of electric ventricular systole (A. V. Kadyskin, 1966). By studying the electrocardiogram, then, the condition of the most important heart functions — automatism, conductance and excitability — can be judged. This, in turn, makes it possible to observe various forms of damage in heart muscle, to trace dynamically, with the help of the electrocardiogram, the condition of the heart under the prolonged effect of various parameters of noise during chronic experiments.

The pneumogram was recorded with a special potentiometric transmitter. This is a tube made entirely of rubber, filled with graphite dust; connecting wires attached to both ends lead to the recording device. For recording respiratory movements, the transmitter was placed at the base of the thorax of the animals and it changed its length in accordance with change in the perimeter of the thorax. /83

Respiration was recorded in the same period of time in which the EKG was registered. The rate of respiratory movements was studied, as well as qualitative changes, relative depth, rhythm and type of respiration (A. V. Kadyskin, 1966). This data was also statistically analyzed.

In recent years, researchers have begun to use toxicological and biochemical methods to evaluate the effect of noise on the organism in experimental conditions. In the Soviet Union, integrated methods have become very widely used in experiment to study the effect of various deleterious factors on the organism. In particular, these integrated methods of studying the condition of animals under certain practical influences make it possible to detect any unfavorable shifts in the organism. The use of these methods also reveals still latent, but already developing changes in the organism, as they are reflected in its condition as a whole.

It must be pointed out that the use of integrated methods in experiments was also approved by the participants in the Prague International Symposium on maximum permissible concentrations.

In this connection, it is advisable to use integrated methods to evaluate the effect of noise on the organism of animals (B. D. Zeygel'shefer, 1968). The following integrated methods can be used to evaluate the effect of noise on the organism of animals: recording weight changes in the animals, determining oxygen requirements, determining muscular strength of the animals at rest, determining the length of time the animals can swim, calculating the time it takes a mouse to recover the ability to move in a straight line after brief rotation on a centrifuge, determining the summation-threshold index (SPP) of animals.

Leaving aside discussion of each of these methods, as this has been done in special works (M. L. Rylova, 1964, and others), we feel it necessary to note that in evaluating the effect of noise on the organism, it is important to determine the level of hemoglobin, the number of red blood cells and carboxyhemoglobin in the peripheral blood of animals, as well as the weight coefficients of several internal organs (lungs, heart, liver, kidneys and spleen). The latter, as is known, is an extremely useful index for determining the chronic effect of an unfavorable agent. /84

In evaluating the effect of noise on the organism, there is interest in data obtained with the help of autoradiography — a method making it possible to study the hemato-encephalic barrier penetration for tagged phosphate and the exchange of phosphorous compounds in brain structures.

The brain of white mice, removed from the skull cavity, is fixated by absolute alcohol and enclosed in paraffin. Frontal sections 10 - 12 μ thick are prepared from the cerebrum at the level of the optic lobe (the temporal-parietal portion of the hemispheres) and the mesencephalon (temporal-occipital portion of the hemispheres) and the mesencephalon (temporal-occipital portion of the hemispheres). Then the slices, glued on microscope slides, are placed on RT-1 X-ray film. X-ray cassettes and photographic copying frames were used to create pressure and provide close contact between the section and the photo-sensitive layer. After the exposure to noise was terminated, the films were developed and the sections stained. To increase the resolving power, the autoradiograms are produced on single-ply X-ray film (S. V. Alekseyev, Kh. A. Getsel', 1968).

Considering the great interconnection between the degree of oxygen consumed by brain tissue and the functional state of the central nervous system, determining the oxygen consumed by various sections of the brain is extremely important to study the effect of various parameters of noise on the organism (Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, A. V. Kadyskin, V. N. Vorontsov, 1970).

When the noise is stopped, the animals (white rats) are decapitated, and the brain removed from the skull, after which corresponding sections of the brain are extracted, pulverized to the consistency of thin gruel and placed in a small reaction vessel with a Krebs-Ringer-phosphate mixture with a pH of 7.35 - 7.4. Oxygen consumption is studied in a Warburg apparatus at 120 oscillations per minute for an hour. Subjected to the study were the cortex of the temporal, parietal, occipital and frontal areas of the brain, as well as subcortical formations — colluculi, thalamus and hypothalamus, after varying exposure to the effect of stable and pulse noise.

The use of these methodological processes to study the effect of noise on the organism in experiment, as well as clinical-physiological and industrial research, will make it possible to obtain a composite idea of the different damage in the organism under the effect of various parameters of noise.

CHAPTER III

THE EFFECT OF NOISE ON THE HUMAN ORGANISM

Almost 2000 years ago, people knew about the harmful effect of noise. In 47 B. C., the citizens of Rome complained to Juvenal about noise in large houses /85 especially from the bellowing of cattle being driven along the street. Since the beginning of modern times, the number of complaints about noise has progessively increased, even to the point of legal proceedings. The complaints were primarily against coppersmiths, weavers, etc. Paracelcus in the XVI century was the first to describe occupational diseases of miners, noting their complaints about ringing in the ears, etc.

In 1700, Ramaccini wrote "A Discussion of the Diseases of Workmen," in which he stated that noise causes headaches and diseases of the ear.

In the development of industry, the transition from hand work to machine work brought the noise factor to almost every factory.

Progress in technology is related to the construction of new multicycle and multi-impulse machines, engines, and power hand tools. At the same time, the noise factor has acquired a different character than previously. Its loudness, spectral composition and nature have changed; the approach to evaulating it as a hygienic factor is also different.

If in the middle and at the end of the XIX century, its negative effect was discussed only in terms of the pain of the auditory organ, at the present time

such an approach to the effect of noise is one-sided. Numerous works in the last few decades have shown quite conclusively that noise causes changes not only in the organ of hearing, but also in many other organs and systems of the organism. Clinical observations and experimental research indicate that primarily the central nervous system, the cardio-vascular system, and many others are affected. Noise has a stimulating effect on man, changes his behavior, interferes with the intelligibility of speech, reduces the productivity of work, and increase traumatism.

Therefore, the question has repeatedly arisen of selecting criteria for determining the effect of noise on the organism: should we start with its "damaging" effect or take some other factor for a basis, particularly, difficulty in hearing voices or signals. The latter approaches the noise factor more as a physical phenomenon than a biological one.

Lehmann suggests that the effect of noise be evaluated according to a biological criterion based on the level of loudness corresponding to four degrees: 1st degree (loudness 30-65 phons) has no physiological effect, only mental reactions; 2nd degree (loudness 65-90 phons), besides mental reactions, it causes functional shifts in the autonomic nervous system; 3rd degree (loudness 90-120 phons) — the same reactions plus the danger of deafness; 4th degree (loudness 120-160) can cause paralysis and can act through the skin (evidently, through receptors of vibration sensitivity, — Ye.Ts. Andreyeva-Galanina).

Schwertz (1960) divides noise into three degrees: 1st degree (loudness below 70 phons) causes slight fatigue; 2nd degree (loudness 70-90 phons) functional and pathological changes in the organism; 3rd degree (loudness as much as 120 phons) — besides those which are typical of 1st and second degree, there are changes in the auditory organ.

Both of these schemes can serve to evaluate tentatively the possible effect of noise on the organism. Neither the spectral composition of noise nor its character is considered. Moreover, the biological evaluation is also given in extremely general characteristics. Although, in our opinion, the ear noticeably starts to suffer later than other systems of the organism, we, nevertheless, feel it necessary to start analyzing the effect of noise with it, as a vitally important receptor for human activity which perceives noise stimuli of varying spectral composition, its intensity and character. We must preface this, although very briefly,

with the structure of the acoustic analysor and its function.

Effect On The Organ Of Hearing

Structure of the acoustic analysor. The acoustic analysor is composed of two sections — the peripheral and the central.

The peripheral section includes three parts: 1) a sound collector — the external ear, 2) a sound conductor — the middle ear and 3) a sound perceiver — the inner ear (Fig. 28).

The external ear consists of the auricle,the hollow of which becomes the external acoustic meatus. This is separated from the inner ear by the tympanic membrane or ear drum. The latter is elastic, thereby offering a certain resistance to the acoustic wave which is propagated through the external acoustic meatus. It has a low acoustic resistance at a vibration frequency of about 800 Hz. /87
This, and the fact that vibrations are quickly attenuated in the ear drum, make it a good transmitter to the chain of auditory ossicles. The handle of the hammer is attached to it on the middle ear side. The tympanic membrane does not distort the shape of the sound wave.

The middle ear is a small cavity. The external wall is occupied by the tympanic membrane, the internal wall has two windows closed by a membrane (the round fenestra rotunda and the oval fenestra ovalis).

The inner ear is also called the tympanic cavity. It contains three small bones — the malleus, incus,and stapes connected with one another and with the tympanic membrane, as well as ligaments, nerves and vessels. The handle of the malleus receives and transmits vibrations to the incus, and that in turn to the stapes. A muscle is attached to the handle of the malleus, tensor tympani, which stretches the tympanic membrane; a second muscle, stapedius, is attached to the head of the stapes. The head of the malleus and the two other auditory ossicles have ligaments which are attached at opposite ends to the walls of the tympanic cavity. The head of the malleus together with the incus rotates about a certain axis, forming a crank lever through which vibrations are transmitted from the tympanic membrane to the stapes with a slightly reduced amplitude, but increased pressure. Under the effect of noise, both muscles are contracted, as a result of

which the amplitude of vibrations of the auditory ossicles is reduced thereby protecting the cochlea. The excitation threshold of these muscles parallels the auditory thresholds, but is 30-90 dB higher. /88
The latent period of excitability of m. stapedius is 10-15 microseconds, and m. tensor tympani is longer.

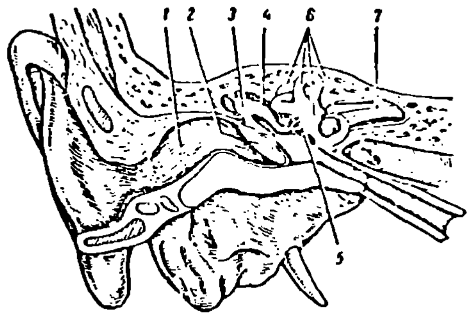


Figure 28. Diagram of the structure of the ear. 1 — external auditory meatus; 2 — tympanic membrane; 3 — Malleus; 4 — incus; 5 — stapes; 6 — cochlea; 7 — auditory nerve.

The inner ear — the labyrinth — is a peripheral receptor apparatus; it also performs the function of balance, accomplished by the semicircular canals. Part of it performs auditory functions — the cochlea, a spirally twisted, bony membrane containing a continuous duct. A bony partition (the so-called lamina spirale ossea) projects from the osseous wall into the cavity of the canal, but not reaching to the opposite bony wall. The basilar membrane (m. basilaris) extends from its free end. Because of this, a cross section of the canal seems to be divided into two parts, forming two passages; the upper is the vestibular scala (scala vestibuli); under it and parallel to it is the second membrane (scala tympani). A thickened part of the basilar membrane (alongside the tectorial membrane) contains nerve cells comprising Corti's organ (Fig. 29). The nerve cells are arranged in two rows, forming the /89
rods of Corti. On their inner and outer surfaces are hair cells; to the outer side of these are attached the supporting cells of Deiters. The membraneous labyrinth of the cochlea is filled with a fluid — the endolymph — and the two parts of the cochlea contain the perilymph; endolymph and perilymph are derived from blood plasma.

The structure of the basilar membrane can serve as a basis for judging its acoustic properties and for constructing a modern theory of hearing. The basilar membrane is composed of individual, uniformly arranged fibers (they number from 13,000 to 24,000, according to various authors); they are very elastic and resemble strings. The basilar membrane is not of even width. At the base of the cochlea it is 0.05-0.1 mm wide, and at the apex (near the helicotrema) — 0.5 mm. Accordingly, the strings are also of varying length.

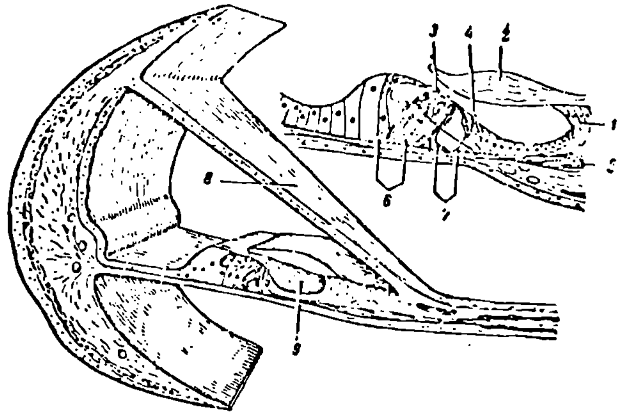


Figure 29. Corti organ and the auditory nerve ending. 1 — osseous spiral lamina; 2 — tectorial membrane; 3 — inner hair cells; 4 — outer hair cells; 5 — basilar membrane; 6,7 — inner and outer arcs; 8 — membrane of Reissner; 9 — spiral canal.

The auditory nerve is composed of nearly 30,000 nerve fibers, consisting of a central cylinder with a myelin sheath.

The pathways of the conductors of the acoustic analysor contain a large number of complex intermediate centers located along its entire length from the peripheral end to the cortex.

The auditory stimuli pass along the central branches of the bipolar cells of the spiral ganglion (these branches form the cochlear nerve) to the dorsal nucleus of the auditory nerve or the acoustic tubercule, and on to the ventral nucleus. From these nuclei, the stimuli proceed further along various pathways. From the acoustic tubercule along the axons of their cells, they pass under the floor of the 4th ventricle, and part of them crosses to the opposite side. The other part proceeds along the lateral lemniscus into the nuclei of the lateral lemniscus and to the inferior protuberance of the colliculi and enter the medial geniculate bodies.

From the ventral nucleus of the auditory nerve, stimuli are disseminated along the axons of its cells; they reach the upper olive or the nucleus of the corpus trapezoideum on their own and the opposite side. From the inner geniculate

bodies, the stimuli reach the temporal area and terminate at the cortical end of the acoustic analysor.

Mechanisms of conducting and perceiving sounds. Sound vibrations enter the external acoustic meatus, reach the tympanic membrane and cause it to vibrate. Acoustic vibrations are transmitted through the auditory ossicles to the oval window and the cochlear fluid. Movements are transmitted through the fluid to the round window and beyond; this causes oscillation of the basilar membrane. The hair cells are in contact with the tectorial membrane, which stimulates the nerve endings. The tympanic membrane absorbs some of the energy of large-amplitude sound vibrations and acts as a desensitizing factor (G. I. Grinberg, 1957; R. A. Zasosov, 1945).

The entire sound-conducting system of the middle ear acts as a receiver of sound energy, transmitting it from the surface of the tympanic membrane to the surface of the oval window, an area approximately 20-25 times smaller than the surface of the tympanic membrane. Therefore, the sound energy here is much more concentrated. The muscles of the auditory ossicles, mm. stapedius and tensor tympani, are not only reflector regulators of the sound-conducting apparatus, but also protective mechanisms against the effect of high-powered sounds. /90

If sounds of medium frequency and intensity act on the organ of hearing, both muscles are contracted simultaneously, which keeps the auditory ossicles in a state of unstable equilibrium and makes it easier for the tympanic membrane to react to vibrations of varying frequency and intensity. Under the effect of very intense sounds, both muscles are in a state of tetanic contraction, protecting the inner ear from danger.

It is known that sound waves penetrating the external and inner ear pass through the labyrinth fluid of the inner ear to the organ of Corti. From there the stimuli proceed along the peripheral fiber to the spiral ganglion, which is located at the base of the cochlear lamina. Stimuli travel along the central branches of the bipolar cells of the spiral ganglion to the dorsal nucleus of the auditory nerve or the acoustic tubercule (nucl. dorsalis n. cochlearis, seu tub. acusticum) and to the ventral nucleus (n. ventralis, n. cochlearis). Further on, the stimuli travel along various pathways. From the acoustic tubercules along the axons of their cells, forming the acoustic striae, the stimuli pass under the floor of the fourth

ventricle and partly cross to the opposite side. The stimuli also travel along the lateral lemniscus and enter the nucleus of the lateral lemniscus, the inferior protuberance of the colliculi and the medial geniculate bodies.

From the ventral auditory nerve, stimulation along the axons of this nucleus, forming the corpus trapezoideum, reaches the superior olive and the nuclei of the corpus trapezoideum on its own and opposite sides. From there, stimuli proceed along the lateral leminiscus to the nuclei of the lateral leminsicus, inferior prominance of the colliculi and the medial geniculate bodies, and from the inner geniculate bodies they reach the temporal area of the brain and terminate at the cortical end of the acoustic analysor.

Thus, auditory stimulation in its simplest form must traverse four serially connected neurons; first — from the organ of Corti to the primary auditory nuclei; second — from the primary auditory nuclei to the inferior protuberance of the colliculi; third — from the inferior hillock to the inner geniculate body, and finally, fourth — from the inner geniculate body to the auditory cortex. However, the large number of other subcortical auditory formations which interrupt auditory fibers indicate that neurons of various orders travel in parallel in the auditory pathways and , therefore, the actual number of serially connected neurons can be much higher.

Besides the basic pathways conducting sound stimuli in the central route, additional auditory pathways have been established: cochlear-cerebellar and cerebellar-cortical. Barnes, Magoun, Ranson (1943) showed that the auditory prominence returns collaterals across superior acoustic striae to the surrounding reticular formation, where a large number of fibers enter from the nuclei of the lateral leminsicus. It has now been shown that, besides the basic, or so-called specific auditory pathway, there is another possibility of sound stimulus penetrating the cortex by nonspecific or reticular auditory pathways (P. K. Anokhin, 1962, and others). Electrophysiological research has shown that, if a sound stimulus enters the projection zone along a specific pathway, it causes local changes in the electrogram, while a stimulus along a reticular pathway diffusely proceeds to the cortex and causes a generalized reaction of the cortex as a whole.

<u>Bone conductance</u>. Transmission is possible not only by air pathways, but also by bones. This is called bone conductance. A sound with the very same frequency

and intensity, supplied through air and bones, is in the second case heard more loudly. Békésy, studying bone conductance, concluded that it occurs by means of a complex deformation of the walls of the labyrinth, the walls of the auditory canal and the apparatus of the inner ear, resulting in displacement of the basilar membrane, the same as in air conductance.

To prove this explanation, Békésy acted on the organ of hearing by bone conductance with 400 Hz sound and at the same time supplied a sound of the same pitch, intensity, and phase which could be varied. The second sound ' be selected so that the ear stopped hearing anything, i.e., one sound has an effect on the cochlea equal to, but opposite in phase, to the other. By this test, Békésy (1932) successfully proved his hypothesis about the effect of sounds when they are transmitted by bone tissue. The threshold of auditory sensitivity with a closed auditory canal and bone conductance is 15-20 dB lower than with the canal open. Békésy attributed the increased sound of bone conductance with the auditory meatus open to the fact that in this case, as a result of periodic deformation of the bony skull, the volume of the auditory canal is also changed periodically, significant variations in its pressure are transmitted, as in the air entry of sounds, through /92 the tympanic membrane and farther. With an open auditory canal, bone conductance needs another explanation. In this instance the sound is transmitted by ordinary air means and bone — by vibration, transmitted by the bones of the skull to the cochlea. There is uneven deformation: deformation of the basilar membrane is much greater on one side than on the other. This causes it to shift.

Vibrations of the stapes with reference to the cochlea provide additional pulsation. Measurements made by the author show that both values are of the same order.

E. A. Masharskiy (1964) conducted interesting experiments on the propagation of acoustic vibrations by the bones of the skull when they are applied to the center of the parietal area. At various points they were expressed differently. The greatest amplitudes were noted in the area of the parietal and frontal prominances. Figure 30 gives the amplitudes, taken from various sections of the parietal and frontal bones. Reduced amplitude was noted by the author in the area of the face, neck, and along the edges of individual bones of the skull and in several other parts. From this, the author concluded that these differences are connected not only with the structure of the bone tissue, but also with the configuration of its sections and the presence of neighboring elements, other biological structures.

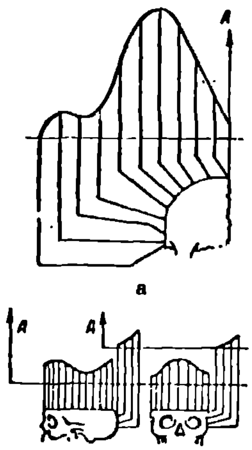


Figure 30. Propagation of acoustic vibrations by bones of the skull. a — graphic representation of the amplitude along the sagittal contour of the frontal bone; b — the same — along the surface of cuts and close to their edges. A — amplitude. The broken line indicates the ascending activating system. The arrows show the double functional connection between nerve centers.

The data of E. A. Masharskiy are of the greatest practical interest. They should be taken into consideration in developing and using various individual means of protecting the organs of hearing. This is especially important when the organ of hearing of blind industrial workers must be protected and when they must keep track of the working order of machines by perceiving the rhythm of their operation. /93

The work of E. A. Masharskiy cannot pretend to contain exhaustive data on the characteristics of perception and transmission of acoustic vibrations to the acoustic analysor by bone, but they agree with the data of Békésy and indicate that the rigidity of bone formations provides a higher level of loudness than transmission by air. The further course of sound vibrations is probably as described by Békésy.

Region of perception of sound frequencies. The human ear perceives acoustic vibrations in a wide frequency range — from 16-20,000 Hz. It has uneven sensitivity to various frequencies. The thresholds of perception of various frequencies differ, and therefore they are heard with varying loudness. The ear is 10 million times more sensitive to high tones than to low ones. The acoustic analysor is least sensitive to frequencies below 100 Hz and over 10,000 Hz. G. I. Grinberg and R. A. Zasasov suggest this is due to the lack, in the organ of Corti, of nerve instruments capable of reacting sufficiently to these frequencies. For the pitch of a sound to be perceived, it must be sufficiently intense and prolonged.

Doughty and Garner (1947) found that the time threshold of distinction increased as intensity weakened. Thus, when intensity is reduced from 80 to 40 dB for tones of 1000 and 800 Hz, time increases from 10 to 22 msec, and for 125 Hz —

from 24-40 msec (cited by S. N. Gol'dburt).

To evaluate the pitch of a sound, it is necessary to know the number of vibrations and the time. For a tone of 128 Hz, 4-5 vibrations are necessary (vibration lasting 30-40 msec). With a lesser number of vibrations, it is perceived as an impact. For a tone of 1,000 Hz, 12 sound waves are necessary, and for 10,000 Hz — 250.

Man perceives tones with frequencies below 50 Hz because these sounds create subjective overtones, which, because of the special asymmetrical construction of the tympanic membrane, allow a somewhat lower sound to be perceived. The highest clearly-determined tone is one with a frequency 10,000 Hz.

The acoustic analysor has great discriminatory ability. The area of perception of frequency differences is characterized by a differential threshold, in other words, by that minimum change in frequency which can be perceived in comparing two discerned frequencies. In the tone range 500-3000 Hz, we can distinguish a change of frequency of 0.003%. For example, for a tone of 1000 Hz with an intensity of 40 dB with threshold changes, the frequencies will be 997 and 1003 Hz. In the 50-100 Hz range, only frequency changes of 0.01% can be distinguished. Acoustic /94 sensation of identical intensity develops from various frequencies at various levels of sound pressure. If a tone at 1000 Hz is perceived with a pressure of $2 \cdot 10^{-4}$ $dyne/cm^2$ or $2 \cdot 10^{-5}$ n/m^2, a low tone is perceived with a pressure about 1 $dyne/cm^2$. At lower pressures, no auditory sensation develops.

The degree or intensity of the auditory sensation is related to the physical characteristics of sound.

The medium surrounding man, especially in industry, contains a complex combination of sounds.

The acoustic analysor has the ability to differentiate most delicately, and reactions to a sound stimulus seem to be instantaneous. However, this is only a subjective sensation. Hundredths or tens of seconds pass from the moment the stimulus is given to the subjective sensation of the sound.

In natural conditions, man perceives complex combinations of sounds. The

elementary sound frequencies of which these combinations are composed can follow one after the other with extreme rapidity; therefore, it is important to know with what accuracy the human brain registers their changes in time. S. N. Gol'dburt dealt with this important aspect of the neurodynamics of the auditory system in her monograph, one of the outstanding works in this area (1964).

The studies also showed the importance of the time factor in separately distinguishing two sounds following one after the other and the merging of discontinuous sounds into a continuous sound.

Miller and Taylor (1948), on the basis of research concluded that the auditory organ reacts not only to the spectrum of a sound stimulus, but also to its time characteristics. The minimum distinguishable interval of time between sound stimuli is 0.5-3 msec. One is evaluated as stronger than the other. Békésy and others have determined the duration of attenuation of the auditory sensation; the criterion was the distinct succession of sounds. With an attenuation interval between 80-140 msec, the sensation remains stable. With shorter intervals of discontinuous white noise, breaks are perceived. The time of distinguishing the discreteness of two auditory stimuli of the same intensity can be very short — 1.5-2.0 msec (A. A. Volokhov and G. V. Gershuni, 1935). S. N. Gol'dburt (1964), employing two electroauditory stimuli of differing intensity, discovered that the length of activity developing in the acoustic analysor in response to a brief stimulus, can be very great and can even exceed the physical length of the stimulus. The following types of effects were discovered: residual effect I of stronger stimulus on the threshold, loudness and timbre of stimulus II, and the reverse effect II of a stronger stimulus on the threshold, loudness, and timbre of stimulus I.

The studies led the author to conclude that the first processes which she observed in perception and evaluation of acoustic vibrations, did not occur in the peripheral section of the acoustic analysor, but at one of its central levels. /95

Research conducted in recent years, especially on the electrophysiology of auditory processes, proves conclusively that elementary differential discrimination of a huge range of sounds, perceived by the organ of hearing, does not occur only in the peripheral element. Undoubtedly, a sound, dissociated in the cochlea into its components, stimulates individual nerve elements. Cortical centers of hearing analyze and synthesize these pulses into a general auditory impression.

Brilliant works in the field of morphology and physiology of the acoustic analysor, with accurate electromicrophysiological studies, compel us to approach the evaluation of tonality in a new way. Some researchers are advancing the hypothesis of a specific design of nerve activity for each tone, composed of islets of stimulation and inhibition between inactive neurons.

Perception of sound intensity. The intensity of an auditory sensation, evaluated by man as the loudness of the sound, depends on the frequency of nerve pulses sent from the receptor of the organ of Corti along nerve fibers to the brain centers. Variable electric voltage potentials are found in the cochlea — cochlear currents. The frequency of these variable currents corresponds to the frequency of the acoustic vibrations acting on the ear. The voltage of the electromotive force of the cochlea is proportional to the intensity of the sound. These cochlear currents can be detected with special equipment; the ear behaves, in the opinion of several researchers, like a microphone.

Man has the ability to characterize the intensity of sound, to differentiate one tone from another, and its shades, pure tone from noise. The ear determines the direction of sound.

The study of the differential threshold of hearing indicates that the ability to differentiate changes in the intensity of sound depends on its frequency. The minimum perceptible increase of sound intensity does not remain constant and depends primarily on the initial intensity of the sound. In order to sense differing loudness when two sounds of different intensity are given, it is necessary that the increase in sound intensity be approximately 10%. In other words, the ratio of intensity of two sounds must be a certain constant value so that the change in loudness can be sensed.

Weber-Fechner established the mathematical dependence between the intensity of sound, its frequency, and the auditory sensation. With a gradual increase of intensity (its energy), the sensation of its loudness will also increase. It will increase in proportion to the logarithm of the sound intensity. If the level of sounds is expressed in sound pressure (N/m^2) or intensity (W/m^2), the entire area of auditory perception of frequencies would be expressed by a vast range of degrees of loudness—as many as 340,000. To cover such a wide range, we use the logarithmic scale of loudness, according to which the transition from one graduation to the

next does not correspond to a change of intensity of one unit, but a certain number of times. If, for example, the energy flux for the first stimulus is I_0, and for the second — I, the sensation of loudness increases accordingly $\lg I - \lg I_0$.

Each degree of such a logarithmic scale, corresponding to a 10-fold change of intensity, is called a bel. In acoustics, a lower unit is used — 0.1 bel, called a decibel (dB). Then the level of sound intensity in decibels can be expressed by the formula:

$$L = 10 \lg \frac{I}{I_0} \text{ dB}.$$

The intensity of the sound (I_0) or the pressure (P_0) is used for comparison. The threshold value of sound pressure is $2 \cdot 10^{-5}$ N/m^2 and the intensity of the sound — 10^{-2}W/m^2 for a tone with a frequency of 1000 Hz. If sound pressure (P) is compared, instead of intensity, then the formula assumes the following form:

$$L = 20 \lg \frac{P}{P_0} \text{ dB}.$$

Increasing the level 1 dB corresponds to increasing the sound pressure 12% or the sound intensity 20%.

The entire intensity range fits into 130-140 units (dB), which makes it possible to operate with small amounts.

Level of loudness. The logarithmic scale determines only the physical characteristics of sound, not the physiological. The auditory apparatus is not uniformly sensitive to various acoustic frequencies, which has been mentioned earlier. For a physiological evaluation, a scale of loudness levels has been introduced, composed of the properties of the hearing organ, to judge sounds with varying frequency according to loudness, i.e., judging which of them is stronger or weaker. The unit determining the level of loudness is the phon. The level of loudness in phons of any noise or sound is determined by a subjective comparison of their loudness with a 1000Hz sound. Figure 31 presents curves, compiled by Robinson and Dadson, approved by the International Organization of Standards as norms and recommended for use.

In examining these curves, we note their convergence at low frequencies and with low levels of loudness, but there is a separation between the numerical values of phons and decibels. For example, a tone with a frequency of 100 Hz with a sound intensity level of 40 dB creates a level of loudness of about 35 phons. In proportion to the increased frequency of sounds, the levels of their intensity and loudness converge. At low frequencies, the level of loudness changes more rapidly than the level of sound intensity, and changes in intensity of a few decibles can change the level of its loudness by 10 phons.

It can be concluded from the curves of equal loudness that quantitative differences between phons and decibels (i.e., between the level of loudness and intensity of sound) are greater, the lower the frequency of sound and the weaker it is. In proportion to the increased intensity of the sound, the curves of equal loudness gradually equalize, and in the high-frequency region (beginning with 4000 Hz), they rise again forming a slight dip at a frequency of 4000 Hz.

By using the scale of loudness levels, the nonuniformity of frequency characteristics of hearing in the perception of individual frequencies can be quantitatively evaluated. It does not clarify other aspects of the sound function, particularly subjective loudness.

The question of the interconnection between the loudness level of a noise or sound and the resultant subjective sensation has been developed by a number of researchers (S. N. Rzhevkin, 1936; Fletcher, 1940; Zwicker, 1952, 1956, 1958 and others). As a result of these studies, a scale of loudness levels was compiled, based on the physical characteristics and human perception of loudness. The authors used the following interrelations: if the level of loudness is increased two phons, subjectively this is evaluated as doubling the loudness of the sound. If, on the other hand, it is reduced, the sensation of loudness is reduced a corresponding number of times. The loudness of a sound with a frequency of 1000 Hz and a level of loudness of 40 phons is used as the unit of this subjective loudness. This unit is called a sone. The ratio between sone and phon units is given in the nomogram (Figure 32). The nomogram was recommended by the International Organization of Standards as a norm.

The auditory function is subject to age change (Figure 33). A change in the threshold occurs at the same time at various frequencies; it is most pronounced in the area of high-frequency perception. Besides age, individual traits of the

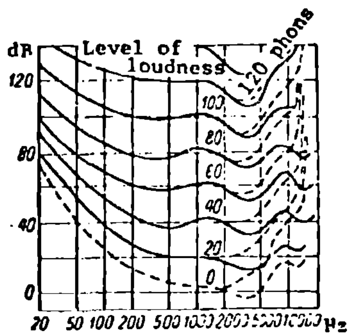


Figure 31. Curves of equal loudness, according to data of Robinson and Dadson. Solid line — age 20 years; dashed line — 60 years. Horizontally — frequency of sound; vertically — level of sound pressure.

organism are also important, as well as his somatic condition, which has a varying effect on the perception of sound vibrations.

A pure tone is perceived when the acoustic vibrations have a regular (periodic) character. This creates the sensation of a pure tone. Noise is a complex of sounds of varying frequencies and intensity. Therefore, we must not assume that the perception of the loudness of a complex noise is the same as that of pure tones. As research has shown, the frequency range of auditory perception can be divided into 24 "critical frequency bands." The sensation of loudness in one band is proportional to the mean square value of the sound pressure in that frequency band (Table 23). Yu. M. Il'yashchuk (1964) indicates that in summarizing loudness in several bands we must consider the effect of masking, which affects the sensation of loudness. However, neither must the frequency characteristics of hearing be disregarded. Cremer (1951) advanced the hypothesis of a two-stage analysis of sound by the hearing organ. The widest-band analysis is made by the basilar membrane of the cochlea, and in the central nervous system. Békésy made interesting studies in this direction. He originally was successful in showing, by the above methods, that under the effect of various frequencies, a traveling wave develops in the cochlear section of the inner ear, and not simple resonance. At the same time, he did not deny that the traveling wave very closely resembles the resonance figure.

The resonance theory of hearing, developed by Helmholtz, was the first based on data of the anatomical structure of the organ of hearing and experimental research of processes which occur in the cochlea under the effect of separate acoustic frequencies. Helmholtz felt that the traveling wave reaches a maximum at a certain point of the membrane. Békésy showed experimentally that resonance /99
of the basilar membrane in response to a pure tone is broad, diffused at the adjacent frequencies, and that the maximum point is important for a sensation of pitch.

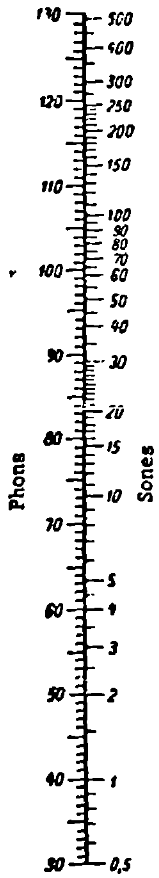


Figure 32. Nomogram of ratio of phons and sones.

Mechanical phenomena are quickly attenuated in the cochlea. This was the basis for Békésy's theory that the cochlea has been adapted to function as a frequency analysor. The works of these authors also indicate that vibration of the basilar membrane and structures connected to it is the basic process of the auditory mechanism, and that frequency perception is signaled to the central nervous system from the point of maximum displacement of the basilar membrane. The research of a number of other authors, conducted on guinea pigs, has shown that the microphone effect can be caused by any frequency stimulating certain parts of the basilar membrane. The character and amplitude of developing vibrations are determined only by the frequency of the effective sound, while the value of intensity is expressed in the increase (or decrease) of stimulation at a corresponding point of the basilar membrane and its extent to a wider area, which also creates a certain figure.

With a broadening of the noise spectrum, stimulation along the basilar membrane /100 encompasses an increasing number of its critical sections, and the more the loudness of the perceived noise increases. As this loudness depends on the width of the frequency spectrum of the noise, it must be measured in special units — lauts (Zwicker, 1958). The resulting loudness in these units is determined by the integration of the specific loudness along

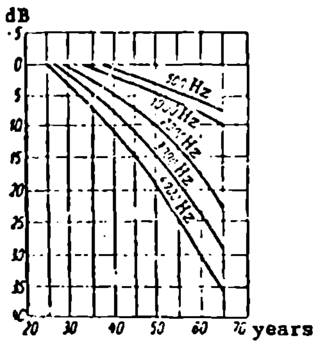


Figure 33. Age changes in the auditory function.

the basilar membrane with consideration for masking.

The perception of the loudness of pulse noise differs from that of a stable noise. First of all, it does not depend only on the maximum or effective sound pressure, but on its form and length. Vibrations of the tympanic membrane under the effect of pulse noise are attenuated extremely quickly (2-3 msec). Therefore, the timbre of pulses, whose duration is less than this attenuation time is subjectively evaluated as identical, irrespective of any dependence on frequency of pulse filling or its duration. This is explained by the fact that in this case the tympanic membrane always vibrates at the same frequency. Yu. I. Il'yashchuk thinks "that one of the features of the time characteristics of hearing is that, for determining by ear the timbre of the sound pulse, it must be no less than several milliseconds in duration."

The experimental research of Niese (1963) successfully established the dependence of the loudness of sound pulses on their tracking frequency, on the duration of the pulse and the intensity, i.e. factors which characterize the subjective sensation of loudness.

In natural conditions isolated sounds are not perceived, but their complex combinations. Elementary sound phenomena, of which these combinations are composed, can follow one after the other extremely rapidly; therefore, it is important to know with what accuracy the human brain reacts to their change in time. The human brain is capable of very delicate differentiation; the reaction to external stimulation seems to be instantaneous. But this instantaneousness is only apparent — hundredths or tenths of seconds elapse from the time of a stimulation to the instant man hears the sound. Changes in the differential reaction are important not only theoretically, but also practically. Man is surrounded by an innumerable variety of stimuli with continuously changing parameters. The speed with which he reacts depends upon the speed and accuracy of their reflection to the brain, neurodynamics. The acoustic analysor differentiates a wide range of noise discontinuity (as many as 1000 interruptions per second) and distinguishes

TABLE 23

CRITICAL BANDS OF THE AUDITORY PERCEPTION OF FREQUENCIES

No. of critical band	Average frequency of band, Hz	Band width Hz	No. Of critical band	Average frequency of band, Hz	Band width Hz	No. of critical band	Average frequency of band, Hz	Band width, Hz
1	50	100	9	1000	160	17	3 400	550
2	150	100	10	1170	190	18	4 000	700
3	250	100	11	1370	210	19	4 800	900
4	350	100	12	1600	240	20	5 800	1100
5	450	110	13	1850	280	21	7 000	1300
6	570	120	14	2150	320	22	8 500	1800
7	700	140	15	2500	380	23	10 500	2500
8	840	150	16	2900	450	24	13 500	3500

one frequency from the other. The study of the time parameters of the auditory system has become very important.

The minimum discernable time interval between two sound stimuli has been established at 0.5-3 msec. This interval is not perceived as a pause between two sounds, but it is sensed as a doubling, a nonuniformity, a discreteness of auditory perception. Only when there is an interval of 80-140 msec between the sounds is the attenuation period of the sound effect completed, i.e., the first sound stops being heard and does not cover the one following (Békésy, Urbantschitsch, 1988; Miller, 1947). After 20-30 msec, nerve signals reflect a decrease of intensity (reduced number of nerve pulses). Decay of intensity permits the sequence of stimuli to be perceived. /101

The data of Scholl (1962) indicate that in the formation of the audibility threshold of pulsed noise, an important role is played by the spectral dissociation of the sound into groups of frequencies, but the high selectivity of hearing is not constant. Brief sound signals are distinguished, and their

audibility threshold is determined by the total energy. If the pulses are long, as with noise, because of its spectral dissociation, only the intensity of one group of frequencies acts. The author made an attempt to determine the time necessary to dissociate the sound spectrum into groups of frequencies. According to his data, it was 10 msec. This is hardly a basis for assuming that such spectral dissociation is completely effected only in the peripheral section of the analysor; without doubt, its central link, which is less well known, is also very important. Research must be undertaken in that direction also. The effect of pronounced and frequent rhythmical sound effects on conductive pathways and cortical centers was studied by Y. A. Al'tman (1961), who found the most pronounced changes in their action in central links of the acoustic analysor. He also noted that the mechanism of frequent and infrequent rhythmical sound stimuli is different. In spite of the great contribution to understanding the mechanism of pulsed noise made by Ya. A. Al'tman, nevertheless, the problem of damage to the acoustic analysor still remains unresolved.

The stimulating effect of sounds. The level of loudness cannot completely determine the stimulating effect of sound or noise. High frequency sounds have a stimulating effect even at low intensities. The sensation of "unpleasantness" does not coincide with the sensation of loudness; it develops with increased frequency, begining at 700 Hz. Thus, a tone with a frequency of 1000 Hz, with a level of 70 phons, seems as unpleasant as a low tone with a frequency of 200 Hz and a level of 90 phons; a 4000-cycle tone with a level of 50 phons is as unpleasant as a low tone with a frequency of 200 Hz at a level of 90 phons. The practical conclusion can be drawn that in evaluating the harmful effect of noise, and in developing technical measures to reduce noise, it is first of all necessary to direct attention toward combatting high-frequency noise. /102

The stimulating effect of sounds and noise can appear in various subjective sensations such as an unpleasant "feeling of tickling," and "tactile sensation." These sensations are connected with excessive stimulation of the acoustic analysor, its overloading. Figure 34 shows sound pressures and frequencies of sound stimuli, which cause various sensations. These sensations appear early in the subjects, but they complain later.

Masking of sounds. In physiological acoustics, without doubt, the absorption of one sound by another, i.e. masking, is very important if they are perceived by

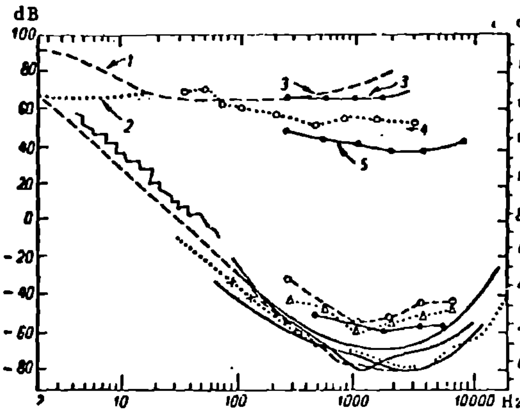


Figure 34. Curves of audibility and sensation thresholds. 1 — slight pain; 2 — "contact"; 3 — "tickling"; 4— "tactile sensation of sound"; Vertically: left sound pressure as compared to 1 dyne/cm^2; right — to 0.002 dynes/cm^2.

the organ of hearing at the same time. The effect of masking was first described by Mayer (1876), Wegel and Lane (1924). As a criterion, they used the increase of the audibility threshold by a certain number of decibels. The authors experimented with various masking tones and levels of loudness (20-100 dB). The closer the masking and masked tone were in pitch, the more pronounced the masking effect. If this difference is small, pulsations are formed, which favor the perception of /103 one tone against a background of the other, which decreases the masking effect. With sounds of a weak intensity, likeness is formed of the resonance curve with a depression at the apex due to the formation of pulsations which facilitate the detection of the masking tone. From their data, it can also be concluded that the masking effect of a tone with a frequency of 800 Hz and a loudness level of 100 dB will cause, for example, the audibility threshold of a 2000 Hz tone to be increased by almost 80 dB, and for 400 Hz — 10 dB. Tones lying below the masking sound are always absorbed more weakly than the more strongly masked sounds above.

Masking is most strongly pronounced in the area of tones close to the masking tone. This happens especially when the sound intensity of the masking tone is raised. The masking effect of a tone of 3500 Hz with an intensity of 100 dB is displayed by the increased audibility threshold of a tone of 3600 Hz to 83 dB, and a tone of 200 Hz to 20 dB.

The masking effect of low tones such as, for example, 200 and 400 Hz, is very great at high levels and extends to the entire frequency range, and in the area of overtones even exceeds the masking in the area of the basic tone. For low frequencies, there is almost no mas 3. S. N. Rzhevkin explains the intensification of masking at high tones by the formation of subjective overtones. S. N. Gol'dburt determined the amount and time dimensions of the direct effect of tone I on the threshold, loudness, and length of tone II (residual masking) and the reverse effect, i.e., the effect of tone II on the threshold, loudness and length of tone I (reverse masking). The author was interested in the length of test tone II, which changes the threshold of masking. Continuing the work of P. O. Makarov on pre-perception, the author studied the reverse effect of stimulus II on threshold I (reverse masking).. Before these studies, the observations of Miller (1947) also detected reverse tonal masking in the 10 msec interval. I. K. Samoylova (1959) found a prolonged (500-600 msec) reverse effect of tone II on threshold of tone I.

S. N. Gol'dburt also determined simultaneous tonal masking, using measurements of the masking threshold of a tone of varying length. The author selected two brief tones and studied the discrimination of loudness and sequence, depending on the duration of both tones and the interval between them.

Masking of one sound by another is connected with those processes which occur in all links of the acoustic analysor.

S. N. Gol'dburt gives this definition of masking: "It is primarily a condition of more or less strong stimulation, accompanied by "covering" of homogeneous, weaker stimuli. Frequencies different from the masking frequencies are "covered" because of the excitation caused by the masking tone, i.e., because of its general characteristics with excitation dominant at that moment in the acoustic analysor. Therefore, masking is the inability to respond to an additional stimulus because the reacting instrument is occupied, i.e., it is a decrease in excitability as a result of existing activity."

The masking effect of noise is also greater than that of the sinusoidal sound frequencies. For example, the threshold of audibility is increased 50 dB in the area of a 4000-cycle masking tone; the masking effect is reduced in both directions. Each frequency band with sound energy equally distributed throughout the spectrum primarily masks sounds whose frequencies fall in this band. An interesting phenomenon is observed — each frequency band of noise with sound

energy evenly distributed throughout the spectrum (white noise) masks most effectively the sounds whose frequencies fall in this band.

The practical importance of masking is great, since under noisy conditions it interferes with speech and sound signal intelligibility and makes it more difficult to keep track of machine operation by hearing.

Intelligibility of speech under noisy conditions. The interfering effect of noise can be determined by the intelligibility of speech. Maintaining the latter under noisy conditions is very important, both from the aspect of person-to-person contact and the danger of industrial work. Finally, weakening voice intelligibility undoubtedly also affects the human psyche. Conversational speech is regularly perceived in frequencies from 800-2500 Hz; some have a greater range, 250-2500 Hz. The good perception of the extreme lower frequencies of this range is due to the fact that it is characteristic of vowels composed primarily of low frequencies. To perceive whispered speech, it is important to distinguish clearly the consonants, whose formants lie in the high-frequency range. Reduced perception of whispered speech is often observed with the preservation of conversational intelligibility. Speech intelligibility can be evaluated by the percentage of correctly perceived words; a specially composed table is used. If 60 or 80 words are distinguished out of 100, intelligibility of speech will therefore be 60 or 80%. Another means of evaluating intelligibility has been suggested — I. I. Slavin (1964) suggests evaluating the intelligibility of multi-figure numbers, determined by a subject 1.5-2 m away, by points: 0 — completely absent, to 5%; 1— very poor, to 30%; 2 — poor, to 50%; 3 — satisfactory, to 70%; 4 — good, to 85%; 5 — outstanding, 95-100%. /105

If frequencies below 1000 Hz are excluded from the speech spectrum of words or numbers, the intelligibility is reduced only 8%. Speech intelligibility also changes only slightly if frequencies above 2500 Hz are excluded.

Fletcher (1940) graphically depicted the interference to word distinction created by noise (Figure 35). On the basis of research he assumed white noise. We must keep in mind that the normal loudness level of speech lies between 50-60 dB. His curves can be used to determine the reduction of speech intelligibility as follows. If conversational speech has a loudness of 50 dB, to find the conditions affecting its intelligibility, a line is drawn upward until it intersects the broken line running left to right and upwards; it is joined at the point of their intersection, which will correspond to white noise of 50 dB. A horizontal line

is drawn along the ordinate axis from the intersection line. It will be joined at the 0.25 figure, which corresponds to a one-fourth reduction of intelligibility of words. In hearing damage often connected with age or deafness resulting from noise, these high frequencies elude perception earlier than others. In some cases normal audibility of conversational speech is retained, but perception of whispered speech is disturbed. The intelligibility of speech during noise depends on the loudness of the speech and the noise, their ratio and the spectrum of the latter. In rooms with a large reverberation time, intelligibility of speech deteriorates. /106
The research of I. I. Slavin showed that under quiet conditions speech with a level less than 20-25 phons is completely obscured. With higher levels, intelligibility is satisfactory, if the level of noise does not exceed the level of speech by more than 10-15 dB. With larger increases, the intelligibility of speech falls, and when the noise level exceeds it by 20-25 dB, it becomes impossible. Noise at 120 phons or higher completely excludes the possibility of understanding speech.

The frequency composition of noise also affects speech intelligibility. We know that it is determined by the area of its frequencies. Noises lying in the frequency range between 800-2500 Hz will absorb speech especially strongly and make it less clear. The highest sound energy in the spectrum of the human voice lies in the range below 500 Hz (50%), but the intelligibility of speech is determined not so much by this range, as that from 800 to 2500 Hz. Therefore, noise which contains sounds in this range especially interferes with speech perception. If they exceed the threshold of speech masking in this band (a given loudness), then speech from a distance of 1 m is made unintelligible.

Perception of sound vibrations by vibration sensitivity receptors. Auditory sensations can also develop with vibration stimulation of the range of sound frequencies of skin receptors. We encounter indications of this in articles published in the Amsterdam yearbook (1700). Later Emil Rousseau (quoted by Roberts, 1932), described the perception of sounds when a violincello is touched with the hands. He then expressed the thought of using vibration sensations in teaching deaf persons "to hear" with their fingertips. In 1926 Collucci described the observation of a certain man, deprived of hearing and sight, who by touching a window pane recognized the type of passing cars, reacted to the noise of crowds and music, distinguished individual words by lightly touching a vibrating telephone diaphragm. The vibration sensation lay in the 16-1500 Hz range, i.e., it also included the auditory frequency range.

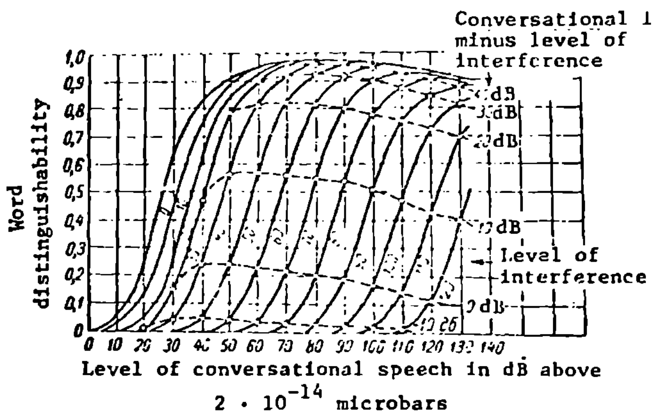


Figure 35. The dependence of word distinction on loudness of speech and level of interference (after Fletcher).

S. M. Dobrogayev (1934) indicated that when perception of sound vibrations is lost by the organ of hearing, they can be sensed through the skin by vibration sensitivity receptors. Later M. S. Mogil'nitskiy (1936) proved experimentally the connection between vibration-tactile sensations and the auditory function, and the effect of vibration stimuli on sound trauma. A. I. Bronshteyn (1946) and G. V. Gershuni (1965) established the accentuation of vibration sensitivity when hearing or sight is lost or blocked.

M. A. Shklovskiy (1939) by his numerous studies showed that deaf people not only have a lower threshold of vibration sensitivity, but that vibration "is perceived as a component of the tactile perception of speech and a component of the uttered word, perceived and mediated in communication and thinking-in-words."

Litereture data indicate that vibration sensitivity is a genetically ancient form of sensitivity. During the long chain of the evolutionary development of organisms from lower to higher, the organ of hearing was formed from the skin. This organ perceives sound vibrations and makes it possible, with increasing accuracy and perfection, to react to acoustic stimuli, to perceive them and evaluate them as signals of a certain character. Erchard (1872) assumed the vibration receptors and their conductors were connected with the central nervous system. He even suggested using vibration sensitivity to diagnose deafness.

Urbantschitsch (1888) and A. G. Nauman (1994) found that vibration sensitivity, determined on the bones of the skull, lies in the range of speech frequencies. The

numerous studies of the thresholds of vibration sensitivity, conducted by Knudsen (1923, 1928), Gault (1930-1936), Goodfellow (1936), Ye. Ts. Andreyeva-Galanina, A. I. Vozhzhova and others, have shown that the lowest thresholds of vibration sensitivity are located in the 250 Hz frequency, and Gilmer (1935, 1937, 1939) found them in the 250-1024 Hz range (Table 24).

TABLE 24. THRESHOLD OF VIBRATION SENSITIVITY ON THE TERMINAL BONE OF THE SECOND FINGER OF THE RIGHT HAND (AMPLITUDE IN CM)*

Frequency, Hz	Ye. Ts. Andreyeva-Galanina (1940-1947)	A. I. Vozhzhova (1952)	V. Ye. Lyubomudrov (1955)	Knudsen (1928)	Gilmer (1934)
60—64	$5 \cdot 10^{-4}$	—	—	$1 \cdot 10^{-4}$	$6 \cdot 10^{-5}$
100—128	$5 \cdot 10^{-4}$	$1,7 \cdot 10^{-4}$	$6,4 \cdot 10^{-4}$	$5 \cdot 10^{-5}$	$8 \cdot 10^{-5}$
250—256	$3 \cdot 10^{-5}$	—	—	$1 \cdot 10^{-5}$	$4,5 \cdot 10^{-5}$
900—1024	$8 \cdot 10^{-5}$	—	—	$1 \cdot 10^{-4}$	$1,4 \cdot 10^{-5}$

*Commas represent decimal points.

Gault trained deaf persons to differentiate between vowels and consonants, as well as individual words. Figure 36 shows the discrimination of words in connection with training.

Knudsen established the amplitude threshold of differentiation at 1 μ; A. I. Vozhzhova — at a frequency of 100 Hz ± 3-5 μ; and V. Ye. Lyubomudrov — ± 6.7 μ. Besides differentiation of intensity, it is also possible to distinguish tonality. Knudson found the ability to determine a change in tone 8% lower or higher /108 than a 256-cycle tone; Dunlap (1913) — 5% lower or higher than a 400-600 Hz and a 128-256 Hz tone; B Gilmer — 2.5% lower or higher than a 400 Hz tone.

To justify the hypothesis of the "sensation of sounds" by fingertips, Pearson (1928) assumed that when the conductors of vibration sensitivity arrive at those parts of the brain crossed by conductors of the acoustic analysor, they accompany them and arrive at the auditory centers of the cerebral cortex. He gives no proofs for this theory. But there is undoubtedly a close connection between the central links of these analysor systems.

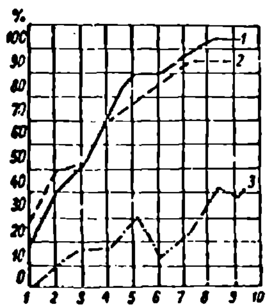


Figure 36. Distinction of words in connection with training (after Gault).
1 and 2 — 250 hours of training; 3 — 60 hours of training.
Horizontally — number of tests, vertically — correct answers.

<u>Theory of Hearing</u>. There are a great many works which deal with various aspects of the function of the acoustic analysor. However, many aspects of the latter have still not been completely resolved, and a theory of hearing, as indicated by G. V. Gershuni and Békésy, has not yet been completely formulated by anyone. Those processes which occur beyond the limits of the cochlea have not been completely revealed. G. V. Gershuni indicates that there is only a theory of the discrimination of the frequency of a stationary sound, a theory, valid for the function of the peripheral link of the auditory instrument — the cochlea.

Sound vibrations reach the cochlea as purely mechanical phenomena and are perceived by receptors of the basilar membrane, which is of varying thickness along its length and is provided with a varying number of receptors.

In 1877, Helmholtz suggested the so-called "resonance" theory of hearing. Later Békésy and others completed it. Helmholtz felt that resonance develops in individual sections of the basilar membrane, caused by its varying width and tension, beginning from the base of the cochlea to the apex. The resonance theory of hearing or, as it is still called, the "spatial" theory, cannot explain the entire auditory function of synthesis and analysis of frequency sounds.

One theory of hearing is based on the "physiological lability" theory of N. Ye. Vvedenskiy — A. A. Ukhtomskiy and the "paranecrosis" theory of D. N. Nasonov.

According to A. A. Ukhtomskiy, under the effect of stimulation, an excitation process develops in the tissues which has a cyclic character. In a certain length of time and after the start of stimulation, excitation begins in the cell, reaches a maximum, and then falls to zero. There is a slight refractory period when the cell remains unexcited. It is known that each tissue has its own rate of return to its original state, i.e., a relative rate of completing the excitation

cycle — physiological lability.

The theory of A. A. Ukhtomskiy about physiological lability can explain the uneven sensitivity of the organ of hearing to sounds of various frequencies.

P. P. Lazarev constructed his own theory of hearing, which is similar to that of Helmholtz. He suggested that there is a sound-sensitive substance whose decay products stimulate endings of the auditory nerve. His explanation for the higher sensitivity of hearing in the area of high frequencies was that they could more easily disintegrate the sound-sensitive substance. P. P. Lazarev was also the first to successfully deduce a law governing change of ear sensitivity under the effect of adaptation to sound in silence, of which more will be said in the section on adaptation. He advanced the important theory that, along with the disintegration reaction, there is a simultaneous recovery process, whose rate is proportional to the concentration of decay products. His law indicates that the force of the effect on the auditory nerve is proportional to the intensity of the sound.

According to his theory, under the effect of intense sounds, the sound-sensitive substance is gradually exhausted; in accordance with this, sensitivity also falls according to the law:

$$E = a + b^{-rt},$$

where a, b and r are certain constants.

The theory of P. P. Lazarev with respect to the recovery of sensitivity after termination of the effect of sounds and its diminution during the prolonged effect of sounds was verified in the works of P. N. Belikov (1925-1928) and A. S. Akhmatov (1925). Opinions on the rate of sensitivity recovery disagree. A. Akhmatov found it to be less than 10 seconds, P. Belikov and Békésy — lasting tens of seconds, A. A. Volokhov (1935) and G. V. Gershuni (1935) — a maximum in 15 seconds, recovery having a phase character.

The theory of Helmholtz and P. P. Lazarev is considered a theory of the peripheral analysor. Therefore, it cannot explain the mechanism of perceiving a number of gradations of sound intensity or several other aspects of the auditory

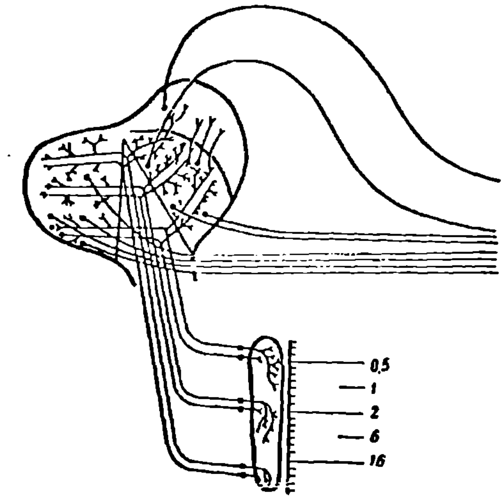


Figure 37. Diagram of projections of perceived frequencies on the receptor surface on the cochlea (after G. I. Ratnikova).

function.

Later, the work of Fletcher (1940) appeared, in which he explained the perception of a wide range of frequencies by the basilar membrane. He advanced an opinion about the effect on resonance of the mass of fluid vibrating at the same time with the resonating fiber. According to the hypothesis of Fletcher, the resonance properties must be transferred to the entire mechanical system of the cochlea. According to his concept, sounds cause vibrations of the membrane along its entire length, with slight maxima at certain sections, depending on the frequency of the tone.

Further studies of the hearing mechanism were directed toward processes occurring outside the cochlea, to a study of the movement of fibers of the auditory nerve from the receptors, located in its various sections, to the cochlear nuclei. It has been established that they are arranged in these nuclei in a certain order which maintains the spatial projection of the expanded cochlea. Fibers from the apex of the cochlea are located in the lower sections, and those from the base of the cochlea, in the upper sections of the nuclei (Figure 37). The fibers of the

auditory nerve, entering the cochlear nucleus, provide ascending and descending branches distributed in three sections of the cochlear complex — anterior ventral, posterior ventral and dorsal nuclei. The projection of the cochlea in the cochlear nuclei acquires another axis besides the frequency axis and is converted into two- or three-dimensional space. This structure, according to a number of authors, provides time apportionment because of the sequence of activated synaptic allotments.

We shall discuss one more work which considers the regulation of the flow of nerve pulses in the auditory system (Ya. A. Al'tman). It indicates that sense organs are a complex self-regulating system with the ability to adapt their characteristics to current activity of the whole organism. Clarification of this complex mechanism of self-regulation is a most important task, particularly as applied to the organ of hearing. In studying cochlear zones, the geniculate body and the auditory zone of the cortex, Ya. A. Al'tman established that the amplitude of responses does not remain the same in all zones.

The first nerve component of the cochlear response is the result of combining action potentials which develop simultaneously in a great number of nerve fibers of the auditory nerve (Goldstein, Kianga, Brown, 1959). The discharge from two different zones seems the same as the result of summarizing the activity of many elements. As G. V. Gershuni shows, not nerve pulses, but the electric potentials developing more slowly in the nerve cells are summarized.

Ya. A. Al'tman used a sound stimulus with an intensity of 60 to 80 dB above the threshold of audibility; individual clicks followed one after the other every 10 msec. Reduction was noted in the amplitude of the primary response of the cortex, the inner geniulate body, and the first nerve component of the cochlea. The amplitude of all 3 zones is changed because each successive stimulus has an effect when the nerve elements do not succeed in recovering their function after the effect of the preceding (10 msec pause) and a small part of the nerve elements will not react to the effect of a stimulus.

When the time interval between stimuli is increased to several tens of milliseconds, the flow of nerve pulses increases rather than decreases, because new active elements are actuated. This phenomenon is treated as the sensitizing of hearing. Interesting research, conducted in the laboratory of G. V. Gershuni and several foreign authors, led them to conclude that, despite the indisputably important data which they obtained, "There is yet no possibility of creating a

general theory of hearing, i.e., a theory of the mechanism of perception and untilization of sounds in all their ranges by the entire organism." We shall present the basic theories formulated by G. V. Gershuni. This material, which is available now to physiologists in the field of physiologial acoustics, gave G. V. Gershuni the right to conclude"that two mechanisms can be distinguished in /112 the auditory system as a whole which differ in many respects — namely, the mechanism of the auditory system in regimes with low and high time constants." If this theory is taken as valid for all sections of the organ of hearing, then, beginning with the cochlea, the existence of elements may be inferred "which are primarily connected with one of these mechanisms."

The basilar membrane has the ability to analyze frequencies with a low time constant, while in the structure of the organ of Corti the time constant can be differentiated ("evidently" — G. V. Gershuni) on the basis of various properties, including mechanical. The basis for this conclusion is in the studies which show that, unlike outer hair cells, the inner hair cells are mechanically adapted to transmit rapidly changing processes.

Properties of the mechanism with a low time constant can be discovered in all sections of the auditory system, beginning, evidently, with the cochlea and ending with the auditory region of the cortex. Signals which arrive in the peripheral section are transmitted in a brief length of time to the corresponding sections of the cerebral cortex. As regards the mechanism with a large time constant as G. V. Gershuni indicates, it is connected with cortical sections which are less clear.

The mechanism with a low time constant is considered as differentiating the spectral properties of acoustic signals in a very short period of time. G. V. Gershuni suggests that this mechanism is not necessarily connected with perception of the chromatic pitch of sound. The mechanism with a high time constant must provide a more delicate differentiation of spectral properties. G. V. Gershuni feels it is inseparably connected with the perception of chromatic pitch and musical perception in general.

Ya. A. Vinnikov and L. K. Titova (1961) indicate that, undoubtedly, it is important to know exactly where and how mechanical resonating movements occur, as they are a triggering mechanism for a number of physical and chemical processes which accompany stimulation of receptor structures and the transmissions of an

impulse to the higher links of the acoustic analysor. Of great interest is that aspect are the works of the school of Ya. A. Vinnikov, in which the biochemical processes of metabolism are being studied, especially the enzyme processes which accompany electric potentials and are the basis of excitation processes. Analyzing their own research and literature data, the authors conclude that the time has come to transfer the emphasis of any theory of hearing to the level of the celluar and molecular organization of the hair cells of the organ of Corti. /113 They are responsible for the perception of sound in the cochlea and its transmission to the central nervous system. Only by these studies will it finally be possible to observe the processes in the central part of the acoustic analysor and to understand the nature of the auditory sensation. Subsequently Ya. A. Vinnikov proposed the cytochemical theory of hearing.

Cytochemical theory of hearing. The essence of the cytochemical theory of hearing is the following (Ya. A. Vinnikov and L. K. Titova). Sonic effects, accompanied by vibrations of structures of the inner ear and the cochlear canal, are reduced to corresponding conversions of mechanical energy to the chemical and quantum ejection of acetylcholine. This causes characteristic dynamic changes in the hair cells of the cochlea (of one of its coils), which are expressed by the rounding off of the cytoplasmatic nucleus, changes in the character of precipitation and sorption of vital stain, etc. Complex alteration processes develop which are connected with the denaturation of the protein component of protoplasm. The authors feel this is only one aspect of the matter. The other, they point out, is that simultaneously with this process certain strictly spatially localized, biochemical processes develop in the excited hair cells of the organ of Corti, corresponding to their structure. Metabolic energy processes, which can be broken down into individual links, and which proceed in strict chain order, underlie in time both sound perception and excitation as well as the transmission of a pulse by the hair cells. The authors call the hair cells chemically-sensitive energy antennae which are depolarized under the effect of "cutting" and "moving" waves, by acetylcholine contained in endolymph. The energy of depolarization activates a chain of exchange processes in the protoplasm of the receptor cell, primarily anaerobic metabolism. The energy of the latter, as the authors suggest, plays a determining role during the excitation of hair cells. This is also indicated by such bioelectric phenomena as the presence of an anaerobic component in the microphone effect and the absence of a pronounced dependence of carbohydrate exchange in the organ of Corti on the total sugar level of the organism. There is concurrent aerobic exchange, rich in the proportion of energy. The energy of

macroergs is used to realize and maintain excitation of hair cells in the organ of Corti. Of great interest is the observation of the phosphatase distribution /114
along a reciprocal gradient, corresponding to the physiological gradient of perception of low and high frequencies by the hair cells along the spirals of the cochlea.

Histochemical research indicates that with a brief sound effect the synthesis of protein increases in the organ of Corti, which coincides with the state of its excitation, and with a long effect, it decreases. Ya. A. Vinnikov connected this reduced synthesis of protein with increased activity of proteolytic enzymes, the dominance of proteolysis over protein synthesis, and the elution of disintegration products from the cells. Acetylcholine is ejected from the body of hair cells in the area of synapses of the spiral ganglion, richly supplied with acetylcholinesterase. The work of the hair cells is under the influence of autonomic central nuclei with the help of the olivocochlear bundle of Rasmussen, affecting the cells through the cholinoergic mechanism.

The specifics of excitation of the hair cells of the Corti organ are due to the characteristics of their morpho-physiological organization at cellular and molecular levels. Different activity — for example, of certain enzymes — develops especially markedly between hair cells which perceive low frequencies (upper spirals of the cochlea) and high frequencies (lower spirals). Ya. A. Vinnikov and L. K. Titova ignore the fact that in the evolutionary development of the Corti organ for the excitation of hair cells a universal "denatured" tissue reaction to sound developed and that the sorption of vital stain is the same during sonic effects for the Corti organ and for other tissues. The latter has been clarified in the classic works of D. N. Nasonov and his associates (1940, 1947, 1950, 1959).

Lastly, which the authors ignore, — this cytochemical theory of hearing does not yet reveal those obscure aspects of auditory perception, especially in the central links, which must be clarified to create a complete theory of hearing. At the same time, this theory illuminates not only those deep processes which occur in the peripheral section of the acoustic analysor, but, it seems to us, it also validates the electrophysiological data widely shown by the works of G. V. Gershuni and his associates, as well as by S. N. Gol'dburt. The cytochemical theory will undoubtedly receive general acknowledgement.

Adaptation. The effect of sounds, as has already been pointed out, leads to a number of processes, primarily in the peripheral link of the acoustic analysor. On-going processes can be detected by electrophysiological means, as well as by the study of biochemical processes, particularly in the hair cells of the Corti organ. We indicated above the data of Ya. A. Vinnikov and L. K. Totova, which /115 are of direct concern to this section — namely, that increased synthesis of protein occurs with a brief effect of sound, and a reduction with a prolonged effect. In the first instance, the excitation process occurs.

With the effect of sounds, processes develop relatively slowly in the auditory organ and after some time cause a change in the sensitivity of hearing. Termination of the sound stimulus is accompanied by restoration of sensitivity. It is customary to determine change in sensitivity by the increased level of the audibility threshold. The physiological accommodation of the organ of hearing to an effective sound stimulus is called adaptation.

A. A. Ukhtomskiy considered adaptation of hearing as a regulation of excitation. Adaptation occurs not only to sound, but also to silence. In the latter case, sensitivity is increased, the ear perceives a sound much louder than after its effect, when it seems weaker. But adaptation also plays a protective role against intense and prolonged sounds (V. N. Boyachek, 1927, 1935; G. V. Gershuni and A. A. Volokhov, 1935; Békésy, 1957). Sensitivity is restored quickly. If adaptation develops in 80 seconds, the reverse process takes 10-15 seconds. A. A. Volokhov and G. V. Gershuni established the phase character of excitability restoration after the effect of a sound with a frequency of 1000 Hz and a loudness level of about 70 dB.

The research of A. I. Bronshteyn, G. V. Gershuni and V. V. Bolkov, A. A. Knyazev (1946) and others showed that adaptation develops not only on the periphery, but also in the central links of the acoustic analysor. At the same time, on the basis of his research, L. Ye. Komendantov concludes that adaptation of hearing is regulated by nerve nodes located along the route of the auditory nerve and the thalamic area, and is effected by efferent (Timofeyev) fibers, leading from subcortical nodes to the Corti organ.

At the beginning of this section, we referred to new data, obtained by Ya. A. Vinnikov and his associates, providing a new approach to the mechanism of adaptation and fatigue. In the light of this research, the ion theory of excitation,

developed by P. P. Lazarev (1916) deserves to be noted. He was the first to derive a law governing the change of ear sensitivity under the influence of adaptation to sound and to silence. He suggested that chemical processes occur in the cells of the Corti organ with stimulation of the cochlear nerve; subsequently, there is the reaction (reverse) of their restoration. With strong sounds the substance is gradually exhausted and sensitivity decreases. This, in his opinion, was adaptation.

Adaptation, as well as the restoration of sensitivity, occurs differently in different people, and it has individual variations. This is indicated by the observations of G. I. Grinberg, showing that changes in auditory sensitivity can /116 be different even under sonic conditions of the same frequency, intensity, and duration. The authors explain this as follows. If hearing acuteness denotes the intensity of the excitory process in the acoustic analysor, the change of auditory sensitivity under the influence of sounds can serve as the intensity index of inhibitory processes, and the time it takes to restore the thresholds characterizes the mobility of both processes.

Although individual sensitivity can greatly mask the frequency and intensity of the sound stimulus, they nevertheless play a role, as does the length of the stimulus, in changing auditory sensitivity. The existence of this dependence is also indicated by the research of V. G. Yermolayev (1937). He established experimentally that, if on stopping sound for 2-3 minutes, the subject recovered his original hearing sensitivity, and subjective sensations disappeared (successive images), then adaptation has occurred; if restoration took more than 3 minutes, fatigue took place.

A. A. Knyazeva noted that high sounds cause a reduction in auditory sensitivity in a wide frequency range; the greatest changes can be in higher frequency ranges than tones of fatigue, which does not agree with the data of Békésy, who observed maximum changes in adaptation to the perception of a tone of fatigue.

G. V. Gershuni and A. A. Volokhov point out preservation of the auditory sensation after termination of the sound stimulus as one of the signs of the adaptation process. Toward the end of the second minute, and especially the third, sensation becomes diffuse, it loses its tonality, which indicates a transitory state betweeen adaptation and auditory fatigue.

The connection between hearing sensitivity and the parameters of the sound or noise stimulus is clearly shown in the research of B. Ye. Sheyvekhman. With the effect of low-frequency sound, changes occur in the perception of low as well as high frequencies. When they are at a level of 70 and 90 dB, the audibility threshold changes by 4-7 dB, and at 100-120 dB shifts in the audibility threshold increase by 12-15 dB.

A sound stimulus with maximum energy in frequencies of 1800-2000 Hz with a total intensity of 70-90 dB in only one minute reduces the sensitivity of hearing at various frequencies by 10-11 dB. After the effect of a stimulus, for example, /117 whose maximum intensity fell at the 3500-4000 Hz frequency, the thresholds of sensitivity to a 4500-cycle tone increased by this number of dB.

In characterizing the state of adaptation and fatigue, it is not only the reduced perception in the high-frequency range that is important. If the high-frequency spectrum of a sound stimulus causes primarily a reduction in the perception of high frequencies, a middle-frequency sound stimulus causes a change in the auditory function not only in the high-frequency range, but also in the lower range (including speech) namely, 500, 1000, 2000 Hz (S. V. Alekseyev, 1965).

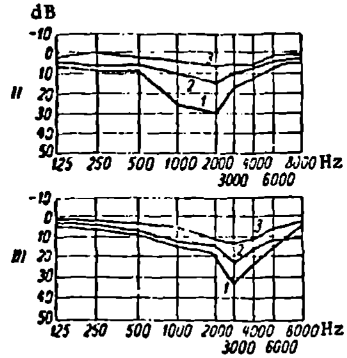
The predominant reduction of perception of 4000-cycle frequency (C 4096) Fowler (1948) was explained as the tension which is experienced by the part of the basilar membrane perceiving this frequency. He felt that this corresponds to the juncture of a perilymph eddy. There is another interpretation of this phenomenon — the delicacy of that part of the cochlea which perceives high frequencies. However, in the light of current data, these hypotheses are hardly completely valid. Not only the frequency and intensity of the stimulus determine the reaction of the acoustic analysor, but the character of the sound stimulus is also important (stability, discontinuity, complexity of the spectrum).

Of particular interest is adaptation to the effect of a complex sound stimulus, whose spectral density is the same throughout the entire frequency range. Ruedi (1952-1959) and A. A. Arkad'yevskiy (1962), studying the effect of such a noise ("white") for 30 minutes and an hour, found a significant reduction in auditory sensitivity in the 4000-6000 Hz range. S. V. Alekseyev and G. A. Suvorov, studying the effect of the same kind of noise with an intensity of 70, 80 and 90 dB, established the same regularities which were noted by the preceding authors — greatest reduction in the threshold of auditory sensitivity at frequencies of

4000-6000 Hz. The lengthened time of restoring the auditory function with 1-hour exposure commands attention. White noise of the same intensity (90 dB), but with a 15-minute action, causes a shift in the threshold at these frequencies by 6-8 dB, and the recovery function takes 8-10 minutes. White noise with an intensity of 70 dB and the same spectral composition (30-1200 Hz) with the effect lasting less than 2 hours, causes not only reduction of sensitivity, but rapid functional recovery. Stabilization of the auditory function, connected with an effective time of 1 hour or more, is due to stable adaptation, which was also indicated in the data of A. A. Arkad'vevskiy (1962 a,b).

With specially arranged research S. V. Alekseyev studied the effect of medium-frequency noise with maximum sound energy in frequencies of 300, 500 and 700 Hz, /118
intensity of 70-80-90 dB, on the functional state of the acoustic analysor. It was shown that, regardless of which of these frequencies contained the maximum energy, reduction of the audibility threshold did not exceed 5-10 dB if the intensity of the stimulus was low (70 dB). When this was increased to 80 dB, with maximum energy at 700 Hz, the threshold of hearing sensitivity was reduced by 2 dB in the 1000-6000 Hz range. Noise with an intensity of 90 dB causes still greater changes in hearing sensitivity, in comparison with stim'li with maximum energy at 300, 500, and 700 Hz. In perceiving frequencies of 4000-6000 Hz, the threshold is increased by 20-25-28 dB, respectively. Restoration of sensitivity occurs 10-15 minutes after the effect of a sound stimulus with an intensity of 80 dB, and 25-30 minutes after a stimulus at 90 dB. Thus, these studies successfully showed that medium-frequency noise in the regions of their extreme frequencies, close to high-frequency noise, has a significant effect on the auditory function. There is a basis for suggesting that temporary shifts in the threshold of audibility, resulting from the effect of a sound stimulus, often bordering on the high-frequency range, cause pronounced adaptation of the ear; sensitivity is restored (similar to that observed with white noise) in a rather long period of time.

Under the effect of octave band noise (300-600, 600-1200, 400-1400) with an intensity of 80 and 90 dB, with an hour's exposure, S. V. Alekseyev discovered the greatest reduction in the threshold of auditory sensitivity in the 1200-3600 Hz range, regardless of the octave band, with an intensity at 90 dB. With an octave band 300-600 Hz wide and an intensity of 80 dB, shifts were small, but at 90 dB the same kind of reaction of the auditory analysor emerged at this frequency band,



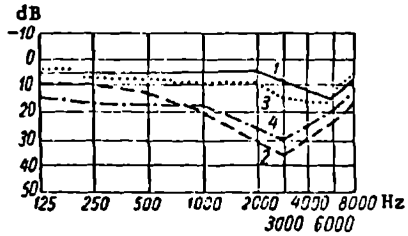


Figure 38. Change in the thresholds of auditory sensitivity after noise (after S. V. Alekseyev). Octave bands: 1 — 300-600 Hz; 2 — 600-1200 Hz; 3 — 1200-2400 Hz. Level of Intensity: II — 80 dB; III — 90 dB.

Figure 39. Change in auditory sensitivity after the effect of noise (after G. A. Suvorov). 1 — stable noise; 2 — pulsed, pulse recurrence frequency 30 per minute; 3 — same, 200 per minute; 4 — same, 1000 impulses per minute.

but less intensely, than at other octave bands (Figure 38).

Pulse noise is of special interest. Depending on the length and frequency of discontinuous noise, Ward (1962) determined the thresholds of audibility. Glorig, Mixon and Ward (1961) even advanced formulae for the increase and decrease /119 of the temporary shift of thresholds, depending on the discontinuity of the noise. L. A. Chistovich (1958) feels that discrimination of discontinuity is determined by the mechanism located at the comparatively low level of the auditory pathway.

G. A. Suvorov studied the effect of pulse noise with a recurrence frequency of 30, 200, 1000 per minute on the organ of hearing (Figure 39). The threshold of audibility was most changed at a frequency of 3000 Hz. Thresholds were reduced at high frequencies by 30-35 dB, with an pulse recurrence frequency of 300 and 1000 per minute. White noise and noise with an interruption frequency of 200 per minute caused a change in the threshold by 15-16 dB at 5000 Hz. The threshold of auditory sensitivity was recovered slowly with complete recovery in 15-30 minutes. Speech intelligibility was reduced; hearing loss for speech was 15 dB at a frequency of 30 pulses per minute, and 10 dB at 1000 per minute. In comparison with the curves of stable noise, they are significantly displaced and only at a repetition frequency of 500 per minute do they almost coincide.

Apostolov (1968) suggests that adaptation is primarily peripheral, as auditory fatigue indicates a more central effect. The author advances an interesting concept in relation to sensitization of the organ of hearing. He feels that it should be considered together with adaptation. If the first characterizes the excitation process in the brain, the second characterizes the inhibitory process, and the second is preceded by the first. Developing stimulation is the reason for increased processes in the peripheral section of the analysor, leading to accentuation of the auditory function.

The author suggests that the state of adaptation after the 3-minute action of noise with a frequency of 6000 Hz should be determined when workers entering industry are examined. To classify the adaptation condition of workers, he suggests the following indices: I — 5-10 dB change in the threshold; II — 10-20 dB change in /120
the threshold; III — 20-30 dB change in the threshold.

According to the author, the most resistant are those who belong to group III, and the least resistant are those in group I.

The author considers fatigue to begin when the threshold changes to 65 dB. Restoration of the auditory threshold is no longer than 10 minutes with adaptation, but in the case of fatigue — it is considerably longer, sometimes even several days. We feel that in adaptation, restoration should begin in 2-3 minutes.

There is, of course, a close connection between auditory adaptation, resistance to noise and the development of fatigue. The more pronounced is auditory adaptation, the greater the resistance of the hearing organ, and the later deafness appears and develops. At the same time, the effect of sound or noise and other stimuli introduces shifts in the auditory function.

G. V. Gershuni et. al. conducted interesting studies on the change in auditory sensitivity with the simultaneous effect of a sound stimulus and the activity of the visual analysor and the neuro-muscular apparatus.

The authors produced data indicating that changes in the state of higher sections of the central nervous system sharply alter adaptation, and that adaptation changes are connected with processes in all links of the analysor. These facts showed that at a frequency of 2700 Hz a fatiguing sound causes

a 9-14 dB reduction in sensitivity in the majority of tests in all subjects. During work, the same fatiguing sound causes a reduction of sensitivity from 0 to 5 dB. At a sound frequency of 1000 Hz, the fatiguing sound without work either causes no change in the threshold or increases sensitivity (+2 dB). During work, the same sound causes a reduction in sensitivity of 4-5 dB in the majority. At the same frequency of the stimulus, in both cases the degree of reduced sensitivity is the same (maximum on the order of 6-8 dB).

The results obtained by G. V. Gershuni in the second group of tests showed that supplying a stimulating sound binaurally causes changes in the adaptation curve, which have common characteristics with those observed in the first group of tests when the fatiguing sound was supplied during work. These binaural changes are expressed in the sharp reduction of loss of sensitivity at a higher frequency than that of the stimulating sound; at a lower frequency, in both groups of tests, changes are not equivalent.

G. V. Gershuni suggests taking a change in the level of the threshold of audibility of 10-15 dB and restoration time of 2-3 minutes as adaptation. /121

If the threshold is changed by a larger number of decibels, there is a certain basis for indicating fatigue. When the question of adaptation and fatigue of hearing is discussed, we must take into consideration the age changes in the threshold of audibility. During the entire lifetime, they remain constant at the lower frequencies; thresholds in the high-frequency range are markedly and quite rapidly lowered (Figure 40.). In this graph, the audiogram of a man 20 years old is used as a comparison.

It is found that, in testing hearing for an hour, the threshold of audibility of a young man may have no marked tendency toward increase or decrease, but in a period of 30 seconds can change as much as 5 dB (Békésy). The threshold can also change in 5 seconds.

The absolute threshold also depends on how long the observer listens. Data on this question have already been presented. Rosenblith (1957) and Miller (1947) found that, in prolonged listening, the threshold can change up to 20 dB for a 4000-cycle tone.

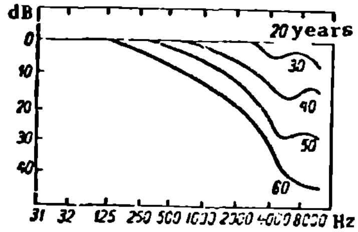


Figure 40. Loss of auditory sensitivity in connection with age.

We must also take into consideration the difference of the age reaction of the organism to the sound stimulus. In examining adolescents, increased sensitivity was found; the most changed is the threshold at high frequencies (6000-8000 Hz). Adolescents working in industry react to noise differently than adults.

V. M. Levin and his associates (1968) examining adolescent ship workers, discovered neuritis of the auditory nerve in 4.1% of the cases. The authors suggest that the presence of this disease in adolescents, who had reported to work healthy, is a result of intense industrial noise and indicates their increased sensitivity to it.

Z. F. Nestrugina (1964) established that reduced hearing of whispered speech is often encountered among those who began working in noisy conditions at the age of 16-20 years. This author also infers the great susceptibility of the hearing organ of adolescents to noise trauma.

I. P. Popov (1967) examined adolescent students (14-17 years) working at milling /122 machines and lathes which create noise with a frequency of 60-1560 Hz, with maximum energy in the milling section at 1600-2560 Hz and 160-2560 in the lathe section. The general level reached 91-95 dB in the first and 86-88 dB in the second. The author found the greatest changes in the 14-15 year old students and more pronounced changes in those working at the milling machines. In the adolescent milling machine operators, the threshold of auditory sensitivity was increased by 20-25 dB in 1 1/2 hours of working in the noisy environment, and in the adolescent lathe operators — 17-20 dB at high frequencies (2000-6000 Hz); at lower frequencies (500-1000 Hz) the threshold changed only by 5-7 dB; in individual cases 10-12 dB. The restoration time of the threshold was different in individual cases: in 14 year old adolescents after 2-3 hours, and in the older students — in 1-1.6 hours. These data indicate that youth are more sensitive to the effect of noise. However, not everyone agrees with this. It is thought that the more significant shift in thresholds of auditory sensitivity does not yet signal more rapid development of

deafness, and that it must be considered as a temporary phenomenon. The question of the relative change in the function of hearing with age is clearly illustrated in the literature. Beginning at age 30, the threshold of audibility increases, and by 50 years of age it is very marked. Subjecting adolescents (17-18 years old) to the effect of high-frequency noise (10,000 Hz) with a sound pressure level of 80 dB, we discovered a greater change in the threshold of audibility during an hour's exposure than in adults. L. Ya. Burlova found significant changes in the threshold of auditory sensitivity 1-1.5 hours after the beginning of class in adolescent girls in a weaving factory-school.

These data imply that the beginning age of workers in industries with high-frequency noise with an intensity of 80 dB or more must be restricted. The importance of the age factor is best seen in experiments without any other attendant factors. The research, conducted by Ye. Ts. Andreyeva-Galanina with a sound stimulus of 10,000 Hz and intensity of 80 dB during an hour's exposure with 17-18 year old adolescents and with a group of 25-27 year olds, showed that in the first group the threshold of auditory sensitivity increased 30 dB at frequencies of 3000 Hz, and 35dB, respectively, at these frequencies. Therefore, it is completely clear, as is seen from these examples, that great shifts are noted in adolescents.

The effect of industrial noise on the organism of adolescents was studied by Ye. A. Gel'tishcheva and I. I. Ponomarenko (1968). Adolescents in industrial conditions were subjected to noise in the 500-6000 Hz frequency range, with an intensity of 100 dB, as well as to noise of 500-4000 Hz (85 dB) and 315-4000 Hz /123 (75 dB). The authors found changes not only in the auditory analysor, but in the cardio-vascular system, a reduction of maximum and increase of minimum arterial pressure.

The vascular tone index decreased, the diastole time of the cardiac cycle, and the time of reflector motor reactions increased.

The functional shifts discovered by the authors in the adolescents are due to their increased reactivity in comparison with adults.

Fatigue. Prolonged sounds or noise of various frequencies and intensities cause adaptation to develop in the organ of hearing, and then fatigue. Both conditions are characterized by reduced auditory sensitivity, i.e., an increase

of its threshold.

Fatigue of the auditory analysor does not occur immediately. It is always preceded by adaptation, allowing a certain period of time to cope with the unpleasant effect of the factor. Symptoms of fatigue are not persistent in the first period; only later does the possibility of pathology develop. To discuss fatigue, we must also consider the pre-pathological condition, caused by overstraining the inhibitory process in the central nervous system.

The fatiguing effect of noise depends not only on its loudness, but on the pitch of the tone as well. Between 64-7000 Hz, the relation is direct, i.e. the higher the sound, the greater its fatiguing effect. Sounds in the 64-1024 Hz range with a loudness level less than 80 dB, according to the data of several authors, do not cause auditory fatigue if the organ is disease-free. Purulent otitis and otosclerosis predispose a more rapid development of hearing fatigue.

The fatiging effect of sounds appears markedly at a frequency of 2048-4000 Hz and a loudness level of 80 dB, 5000-6000 Hz with a level of 60 dB, and 7000 Hz at 40 dB.

By fatigue, Adrian (1932) meant a weakening of the auditory function caused by prior work of the organ of hearing, while adaptation is considered as a reduction of excitability. A. A. Ukhtomskiy feels that fatigue has a biochemical basis, that it is accompanied by a disturbance of phosphorus and carbohydrate metabolism, and changes in the structure of cellular protoplasm, i.e. the processes so brilliantly studied and presented by Ya. A. Vinnikov and his associates.

Fatigue of the organ of hearing, as indicated by G. V. Gershuni, can also be considered as depression, caused by a flow of pulses along centripetal links and a depression of responses — as a case of inhibition of impulses, caused by centrifugal links. Of course, criteria must be established for adaptation as well /124 as for fatigue of the auditory analysor.

An indication of the difference between adaptation and fatigue, besides the dissimilar increase in the threshold of audibility, is the curve of restoration of auditory sensitivity (V. G. Yerlolayev, 1941). In fatigue, the curve has a phase character, the curve of the threshold is uneven, with pronounced descents

and ascents, i.e. sensitivity first incerases than decreases, sometimes the threshold curve remains at the same level. The second difference between adaptation and fatigue of hearing is the time it takes to restore its function. As was indicated earlier, V. G. Yermolayev takes restoration of the auditory function in less than 3 minutes as the criterion for adaptation. Many researchers agree with this time. This time was later verified experimentally by Ye. Ts. Andreyeva-Galanina, S. V. Alekseyev, G. A. Suvorov (1965). If restoration takes more than 3 minutes, fatigue has already taken place. With prolonged repeated sounds, especially noise stimuli, systematically causing fatigue of the auditory analysor. a pattern of sound or noise trauma develops, the basis of which is the change in the receptor apparatus of the organ of hearing (V. F. Undrits), but, to no less degree, also in the central nervous system.

T. M. Radzyukevich (1968) noted interesting facts under the influence of medium- and high-frequency noise which can be used as criteria for judging the development of processes in the auditory instrument. She established that in healthy individuals the shift of temporary thresholds is slight. When working under conditions of systematic and prolonged noise, temporary shifts in the thresholds increase, and the break between permanent shift and temporary becomes constantly smaller.

Systematic noise stimulus causes permanent and temporary thresholds of auditory sensitivity to start to converge, i.e., the threshold determined before the effect of the noise stimulus (after long rest, it is significantly higher) and afterwards. The more the thresholds are shifted, the greater the changes in the acoustic analysor. Besides change in the thresholds and lengthening of its restoration time, there is one more sign which characterizes fatigue, — instability of judging the loudness of a sound and distortion of auditory impressions during complex sounds (S. A. Vinnik, 1940). This has given rise to the assumption that auditory fatigue has not only a peripheral, but a central character as well. However, there are works which indicate that, evidently, at first the entire /125
peripheral section of the auditory analysor suffers.

Effect On The Organ Of Vision

Soviet literature contains a large number of works concerning the interaction of sense organs, in particular, the auditory analysor with other organs. A great deal was accomplished in the interesting research of S. V. Karvkov (1948) and his students, indicating that noise, acting on the auditory analysor, because of the interaction of afferent systems, changes the functional state of many of them.

For a clear representation of the intracentral connections of the auditory analysor with others, we give a diagram illustrating the course of the main nerve pathways, the two-way functional connection between nerve centers and receptors, according to Ye. I. Boyko (Figure 41).

S. V. Kravkov (1948) and his associates established that stimulation by sounds with a frequency about 800 and 2000 Hz or noises of medium and great loudness reduce the light sensitivity of retinal rods (scotopic vision). The noise of an airplane engine (115 dB) reduced the light sensitivity of scotopic vision 20% from that in silence. Ye. N. Semenofskaya, after stopping the auditory effect, observed supernormal increase of light sensitivity of peripheral vision during a rather long period of time. An analogous phenomenon was observed by K. Kh. Kekcheyev and Ye. P. Ostrovskiy (1941) in stimulation with inaudible sounds (33,000 Hz). In the latter case, of course, it is difficult to judge the mechanism by which this reaction develops.

On the other hand, some people respond with increased light sensitivity of scotopic vision during sound or noise (P. P. Lazarev, 1918, 1927; P. O. Makarov, 1936).

V. M. Birinskiy, in examining the functional condition of the organ of sight and its ability to adapt to the intensities of light stimuli acting on it, found that light-sensitivity indices of the eye in the case of dark adaptation of machinists and their helpers, working in noisy conditions, were distinguished by great variableness, even before work.

The same author noted a statistically reliable increase in the light sensitivity in the process of dark adaptation (27%). In laboratory conditions, a reduction of 29% was found, and in reduced illumination — 9%.

Even relatively low-intensity noise (75 dB) causes a reduction of this function. /126

Concerning day vision (cone vision), auditory stimuli of medium intensity increase the sensitivity of the eyes to white light, i.e., the opposite of how they affect the sensitivity of scotopic vision. It varies for different wavelengths. The contrast sensitivity of the eye also is changed.

S. V. Kravkov, stimulating the organ of hearing with sounds of 800 and 2000 Hz and noises of varying loudness found that the sensitivity of the dark adapted eye to blue-green rays is increased, and to orange-red it decreases. /127

Color sensitivity to green does not change immediately, but only after a short period of time. The degree of change in sensitivity of day vision is affected by loudness, time of the effect, and pitch of the sound.

V. M. Birinskiy (1966), studying the ability to make visual distinctions in subjects, found its dissimilar sensitivity to red, green and blue (Figure 42). The subjects were most sensitive to changes in the green and red parts of the spectrum, and least sensitive to the blue section. In the train engineers and their helpers examined by the author, contrast sensitivity decreased in the red part of the spectrum 36%, increased 18% in the blue, and 26% in the green part. The data obtained agree with the observations of S. V. Kravkov. As shown by the studies of V. M. Birinskiy, the uneven distinguishing sensitivity is due to the character and intensity of the noise, as well as to individual sensitivity. The greatest shifts are observed under the effect of 98 dB noise. In the red part /128 of the spectrum, sensitivity was reduced 91%; it was increased 53% in the green and 6% in the blue. After the effect of less intense noise (85 dB), distinguishing sensitivity to the red part of the spectrum was reduced 58.8%, and increased 22.6% in the green part. With a noise of 75 dB, the author observed no marked changes in those subjects observed in the experiment.

High sounds lighten visible light; a lower tone, on the other hand, darkens it.

Other functions of the eye are also changed. In particular, S. V. Kravkov detected reduced critical fusion frequency of light flashes (CFF) under the

influence of a noise with a frequency of 800 Hz and intensity of 85 dB for green light (520 Hz) and an increase for orange-red light (630 Hz). The author's studies showed that the reduction of the critical fusion frequency of light flashes is an indication of increased sensitivity of the eye to rays, caused by the effect of auditory stimuli.

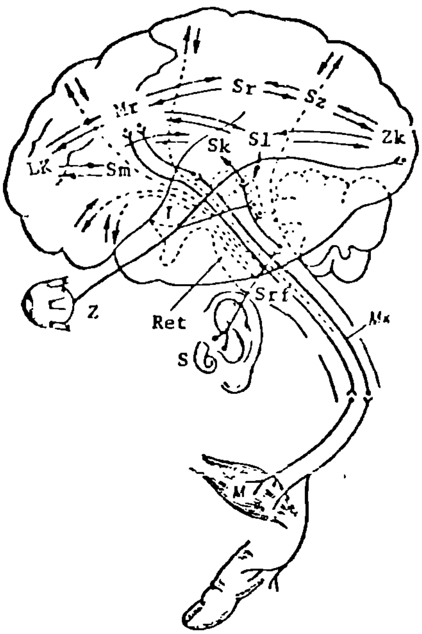


Figure 41. Diagram of main nerve pathways (after Ye. I. Boyko)
C — auditory receptor; Z — visual receptor; M — muscles; Mk — musculo-kinesthetic pathway; Ret — reticular formation; Mr-M — descending motor pathway; Sk — auditory cortex; Sl — audio-vocal zone; Sm — verbal motor zone; Sr — verbal projection of response reaction of the hand; LK — frontal cortex; Srf — lower stem section of the reticular formation; T — thalamic section of the reticular formation.

V. M. Birinskiy, in studying the critical fusion frequency of light flashes in a locomotive crew, observed an average 11% reduction after a trip. The same was observed in acute tests. Noise with an intensity of 98 dB caused CFF to be reduced 12%, but 75 dB noise made practically no change in the CFF. Data obtained on CFF indicate reduced lability in the visual analysor under the influence of noise. Under the effect of the latter, the visual-motor reaction is also gradually changed. The latent period of the reaction to a simple light stimulus as well as to a complex one, is lengthened 14 and 13% respectively under the prolonged effect of 98 dB noise (frequency 50-5000 Hz). The number of errors in the differentiation reaction (to complex stimulus) increases (V. M. Birinskiy, 1966; M. G. Babadzhanyan et al., 1960). The lengthening of the latent period indicates inhibition of the elements of the time connection.

Disturbed equilibrium was also observed in balance reactions to a moving object. The number of accurate responses by members of the locomotive crews was reduced 15% and that of delayed reactions increased 44%, which indicates predominance of

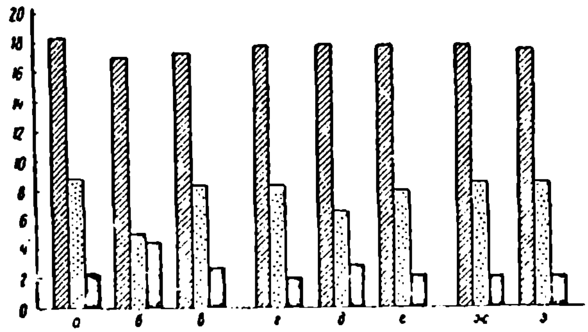


Figure 42. Contrast sensitivity of the organ of vision under the effect of noise.

inhibitory processes in the central nervous system. A distinct connection was established experimentally between the stimulus — the noise — and this reaction. The reaction time of the subjects to a moving object increased in proportion to the increased intensity of noise.

The boundaries of the field of vision change differently under the effect of noise. Broadening of the vision field boundaries is observed with blue and green light, and with orange-red light, just the opposite, a narrowing.

The works of S. V. Kravkov and his associates with extraordinary conclusiveness show that human activity, requiring high distinctive ability of the organ of vision, must be performed under conditions with very low noise intensity. The intensity /129
of the noise stimulus and the time of its action are very important in the reaction of other analysors. Change in the stability of clear vision under the effect of noise depends on the intensity and its spectral composition. The stronger the intensity of the noise, the lower the stability of clear vision. In connection with this, work productivity also decreases — the more the stability of clear vision is reduced, the weaker it is.

A. A. Arkad'yevskiy (1960), in experimental conditions with high-frequency noise with an intensity of 70,75 and 85 dB, studied the time of the latent period of the visuomotor reaction. His studies showed that the time of the latent period also lengthened more, the greater the intensity of the noise.

D. A. Zil'ber (1949) established the dependence between the level of noise and the stability of clear vision. In his tests high-frequency noise with an intensity of 80 dB lengthened the restoration time of clear vision to 1 hour or more. Noise at 70 dB was accompanied by restoration of this function in 20 minutes. Reduction of the stability of clear vision was also observed by L. I. Selitskaya.

Visual chronaxy is lengthened more with high-frequency noise than with low (A. B. Bykhovskiy, 1948).

Depending on the intensity and spectral composition of the noise, the course of successive visual images is also changed.

However, many studies of a number of authors show that a uniform reaction is hardly ever encountered. There are countless associative fibers mutually connecting various sections of the cerebral cortex, but there are also other intercentral connections by means of which changes in one organ can affect others. This is reflected in the interesting research of M. N. Livanov (1960).

These connections, as indicated by S. V. Kravkov, can be cooperative or antagonistic. An important means of interaction of various sense organs is the autonomic nervous system, as was shown by L. A. Orbeli and the experiments of his co-workers.

Current anatomical-physiological data indicate that in man centripetal pulses, coming from the sense organs, penetrate to the optic lobe and the sublobular (hypothalamic) area of the mesencephalon. It is here that the nerve formations are located, the autonomic centers which also determine many reactions of the organism. Therefore, stimulation of a certain receptor, besides the specific effect, can also be reflected in the function of other sense organs. The connection of sense organs with the autonomic nervous system is so close, according to A. M. Grinshteyn, that each receptor can react through the somatic or the autonomic /130
apparatus. Through the hypothalamic area stimulations can also be transmitted to the pituitary gland.

As the activity of sense organs is closely connected with the autonomic nervous system, changes in the latter always overflow, encompassing vast sections of the organism.

The sympathicotropic character of auditory stimuli was proven by Shteyn (quoted by S. V. Kravkov), who observed constriction of vessels in the retina of the human eye in stimulation by a 2034 Hz sound.

All this relates not only to just the visual analysor, changing its function under the effect of a sound stimuli, but to other analysors as well. Neither must we ignore the fact that the phychophysiological background is especially important in the response reaction to any stimulus.

For various reasons, the excitability of various sections of the nervous system can be changed, and their functional abilities change differently; the chain of reactions becomes different. The disturbance of the normal balance between the excitability of various sections of the cerebral cortex and the autonomic nervous system can cause a stimulus, which normally affects one of them, to also affect the other and cause a reaction opposite to the usual one. An analogous phenomenon can also develop if any dominant element appears — a center of increased excitability in the nervous system. A change in the physiological background can also develop because of a change in the intensity of the stimulating and inhibiting processes which regulate the activity of the entire nervous system (I. P. Pavlov).

The Effect On The Motor Analysor

I. P. Merezhkovskiy in 1884 and V. M. Bekhterev in 1911-1915 were, as far as we know, the first to observe in epileptic patients that loud music caused convulsions; later an analogous phenomenon was also observed when sound and noise stimuli influenced them. The stimuli could be of the most varied character — beginning not only with music, but with bells — telephone, alarm clock, etc. L. V. Krushinskiy and others have shown that convulsions are due to the state of the central nervous system.

G. N. Kivitskaya cites the point of view of Servit (1958) on the pathogenesis /131
of the development of convulsions whose formation is connected with the evolutionary development of the nervous system. Servit indicates that convulsions can also be observed at a lower level of phylogenetic development of the brain, as well as at early stages of the phylogenetic development of vertebrates. An inclination toward their development is encountered more often, the higher the phylogenetic development of

the vertebrates. The validity of such an explanation can be, undoubtedly, taken into account, considering that the cortical region of the brain is the youngest formation.

There is considerable interest in those studies which attempt to determine more accurately just which sections of the brain are responsible for the development of convulsions, and if the peripheral section of the acoustic analysor also plays a role. Experimental research has established that removal of the tympanic membrane eliminates the appearance of convulsions with sound stimulation, while removal of even 90% of the motor zone does not eliminate them.

L. V. Krushinskiy and others concluded that in experimental animals (rats), during convulsions and afterwards, both cortical sections and subcortical formations were involved in the pathophysiological process. K. G. Gusel'nikova (1958), using the encephalographic method, concluded that an excitation center is created in the fore part of the medulla oblongata which irradiates along nonspecific pathways to cortical formations. The author explains this by the lack of epileptoid discharges in the auditory and motor pathways at this time. From this she concludes that for convulsions to develop it is not necessary that the arc be closed at the level of the motor zone of the cortex. This can also occur at the level of subcortical structures in the brain stem.

In the light of available morphological research (especially in this respect, we must note the works of L. V. Krushinskiy and G. N. Krivitska) we can give a fairly clear description of the pathogenesis of the development of convulsions, as well as those functional disturbances of the motor analysor which are detected primarily in workers in noisy shops and are expressed in reduced muscular work capacity. An analogous observation was also noted in experimental conditions.

In 1891 V. Boguslavskiy noted a change in muscular work capacity in those who worked in noisy conditions. The research of G. L. Komendantov (1933) verified this observation.

Several authors observed first an increase of efficiency, and then a decrease under the effect of intense noise. In 1933, G. L. Komendantov pointed out that, under the influence of noise, muscular activity indices are changed. At the

beginning of sound, lift and muscle strength of the right hand increases (at the 8th minute), and then they begin to decrease and by the 15th minute they are below the original. Thus, at the beginning there was stimulation, subsequently shifting to depression. /132

Experimental research and clinical data indicate clearly expressed functional disturbances of the neuromuscular apparatus. Z. F. Panayotti (1963) determined the coefficient of dynamography under the effect of medium-frequency noise at a level of 60-100 dB. She clearly established the permanent reduction of dynamography coefficients (an average of 38%) and the motor reaction, recorded from the lower extremities, especially under the effect of 100 and 80 dB noise.

The effect of noise on the neuromuscular apparatus is also indicated by the data of other authors. A. V. Bykhovskiy (1949) and A. A. Konikov (1937) noted considerable, in comparison with the original value, lengthening of motor chronaxy. In experiments on animals, A. V. Bykhovskiy detected fluctuations of chronaxy and the phase character of its changes. In human tests, the author determined the effect of low- and high-frequency noise with an intensity of 40, 60 and 80 dB. With an intensity of high- and low-frequency noise at 80 dB, he observed uneven changes in motor chronaxy; most often noted was lengthening of chronaxy and its significantly higher values with high-frequency noise. The degree of lengthening of chronaxy was less in proportion to its weakening. Motor chronaxy was also studied by O. P. Shepelin (1959). After 15 minutes of pulse noise with an intensity of 70-75 dB, he observed a 40-90% lengthening.

He also found changes in the tone and strength of muscles. A reduction of muscular work capacity was noted experimentally under the effect of noise in the 1600-2000 Hz frequency range with an intensity of 80,70 and 65 dB (E. P. Orlovskaya, 1961). The author evaluated working capacity according to indices of strength and fatigue. After the effect of noise with an intensity of 80 dB, she found strength reduced an average of 25% from the original value, and fatigue increased 11%. The amount of work after the effect of such noise was significantly decreased.

E. P. Orlovskaya very convincingly showed that a functional disturbance of the neuromuscular apparatus does not parallel changes in the threshold of the auditory sensitivity. No reduced strength was observed in the first 2 hours of work, but by the end of the working day it was significantly decreased. She

established that noise with an intensity of 70 dB lowers strength 18%, and noise at 65 dB — somewhat less (16%). Parallel with change of muscular working capacity, /133 the time of the latent period of conditioned-reflex motor reactions — simple and differentiated — increases, and the number of erroneous reactions increases as well, indicating disturbance of the dynamics of cortical processes. Change in muscular work capacity was noted by A. P. Bruzhes and A. A. Arkad'yevskiy (1956), as well as by E. P. Orlovskaya (1962). They noted the phase character of willed motor functions, and A. M. Volkov (1963) observed the inhibited state of the motor analysor in members of locomotive crews.

Influence On The Condition Of Vibration Sensitivity

Determining the condition of vibration sensitivity in transmitting acoustic vibrations by means of the skin is of undoubted interest, as in the past at lower stages of the development of organisms, vibration sensitivity emerged as a prototype of auditory sensitivity. Subsequently, although the ear entirely assumed the function of hearing, the intracentral connection between it and the skin reception, which perceives vibration, was maintained. M. P. Mogil'nitskiy (1936, 1937) proved experimentally that the acoustic analysor is closely connected with vibration sensitivity. The research of occupational pathologists (E. A. Drogichina, N. B. Metlina, 1962; V. B. Lyubomudrova et al., 1968) and hygienists (Ye. T. Andreyeva-Galanina, A. I. Vozhzhova, A. F. Lebedeva and others) shows that vibration, transmitted to the human body, also affects the auditory function. S. Ya. Lifshits proved experimentally that sounds with a loudness level of 112 phons reduce vibration sensitivity by 7 dB.

Of interest are the clinical data obtained by E. A. Drogichina and L. Ye. Milkov, discovering a reduction of vibration sensitivity in workers subjected to noise. L. Ye. Milkov examined the condition of vibration sensitivity in women workers of several industries, where the intensity of noise was as much as 120 dB. The author established an increase in the threshold of vibration sensitivity, expressed variously depending on the level of noise and the length of time working. Thus, with a noise level of 95 dB, the threshold increased by 7.6-9.5 dB, with noise at 103 dB — 8-10 dB. With the noise intensity at 120 dB, the change in the threshold continues to increase. Distinguishing ability is at first preserved, but subsequently deteriorates. L. Ye. Milkov noted a permanent shift in the threshold before work and a temporary displacement after work ended (as much as 11 dB) in /134 those who had been working for a long time in noisy conditions. On the basis of

the theories of V. I. Voyachek (1935), R. A. Zasosov (1945), V. F. Undrits (1935) and others, L. Ye. Miklov justifiably considers that change in vibration sensitivity is due to stimulation of the sacculus by sound vibrations; the sacculus is considered the receptor of vibration perception. With the combined effect of vibration and noise (85-96 dB), T. M. Radzyukevich (1968) detected displacement of thresholds of auditory and vibration sensitivity, both temporary and permanent, as well as their connection with length of time on the job.

The Effect On The Functional State Of The Vestibular Analysor

The effect of sound stimuli on the vestibular analysor is little discussed in the literature, and data obtained are contradictory (V. I. Voyachek, 1927; N. F. Popov; Békésy, 1957).

The research of N. F. Popov (1929), S. S. Grobshteyn and A. V. Kugaro (1931) and I. F. Yenina (1965) indicates that no morphological changes occur in the vestibular apparatus under the effect of pure sounds of medium intensity.

The studies of other authors (G. L. Komendantov, 1933; Békésy, 1935; Bugard et al., 1953; L. Ye. Milkov, 1963 a, b and others) indicate functional disturbances in the vestibular apparatus with certain sound loads, verifying this by the close functional connection between the cochlea and the vestibular apparatus, which follows from physiological development and anatomical localization. V. I. Voyachek (1927) noted that certain people experience dizzyness from sharp high sounds, for example, Galton whistles, and attributed this phenomenon to "irradiation — stimulation jumping from the auditory conductors to the vestibular."

V. I. Voyachek (1935) attributed the sensitivity of the labyrinth to the movement in space of atmospheric pressure changes, vibrations, sound waves, etc. — to general sensitivity to mechanical pressure. Thus, physical energy underlies acoustic damage. Evidently, changes appearing in the vestibular apparatus are due to high sound pressure, which is characteristic of noises and sounds of great intensity. Jansen (1959), in examining those in the metallurgical industry who work under conditions of both intense and relatively weak noises, noted complaints of dizzyness in a number of cases.

Thus, a study of the vestibular function in workers of various industries,

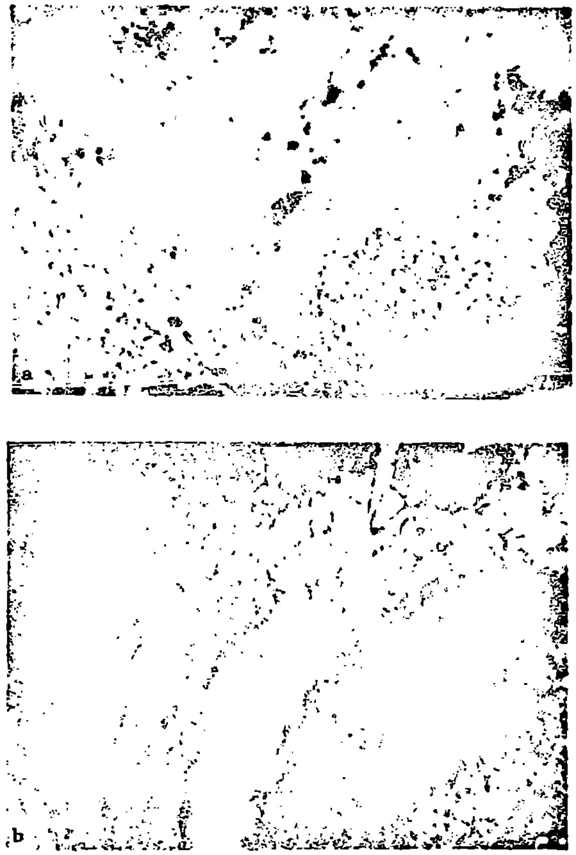


Figure 43. Distribution of acetylcholinesterase activity in the macula utriculi of a guinea pig.
a — no noise effect; b — under the effect of noise with an intensity of 120 dB for 6 hours. Photomicrographs: ocular - 7x, objective - 10x

as well as in experimental conditions with the use of a sound stimulus, indicate that the vestibular apparatus does not remain intact under noise stimulation.

The role of noise in the pathogenesis of functional damage to the vestibular apparatus is still very unclear; especially poorly understood is the effect of a noise stimulus on its sensitive cells. For these purposes, the most suitable method is histochemistry, which makes it possible to record minimum changes occuring in the receptor cells of the labyrinth when it is stimulated. Under the effect of noise with an intensity of 120 dB, changes are observed in the receptor formations of the vestibular apparatus (utriculus, sacculus and ampulla of the horizontal semicircular canal), expressed in reduced activity and disturbed content and /137 distribution of nucleic acids (V. I. Yerokhin, 1969). When exposure is increased (from 1 to 6 hours), the changes became more pronounced.

In a microscopic study of preparations, V. I. Yerokhin observed changes in hair cells nuclei of the utriculus and horizontal semicircular canal (Figure 43 and 44). From the illustrations it can be seen that the karyoplasm of the nuclei was less intensely stained than normally, i.e., there was a reduction of diffuse RNA.

The severity of changes depends on the duration of noise. With the noise lasting 3 hours, the number of swelling nuclei increases. For receptor cells of the horizontal semicircular canal, it was 52%, and for the utriculus — 45%. When the noise lasted 6 hours, the number of swelling receptor cells of the utriculus was 38.5% and of the horizontal semicircular canal — 29.6%, but the reduction in the amount of diffuse RNA was more pronounced than with 1-3 hours of noise (V. I. Yerokhin). In these nuclei, there was a displacement of nucleoli and DNA blocks.

With prolonged daily repeated wide-band noise with an intensity of 120 dB for 1-3-5 months, there was a sharp reduction in the concentration of diffuse RNA in karyoplasm and cytoplasm, many nuclei lacked nucleoli and DNA blocks, some nuclei were close to lysis, while the dimensions of these nuclei did not exceed that of control animals. This evidently indicates the pronounced exhaustion of proteins connected with RNA in receptor cells and the inability of these nuclei to effect "rhythmical functional pulsation."

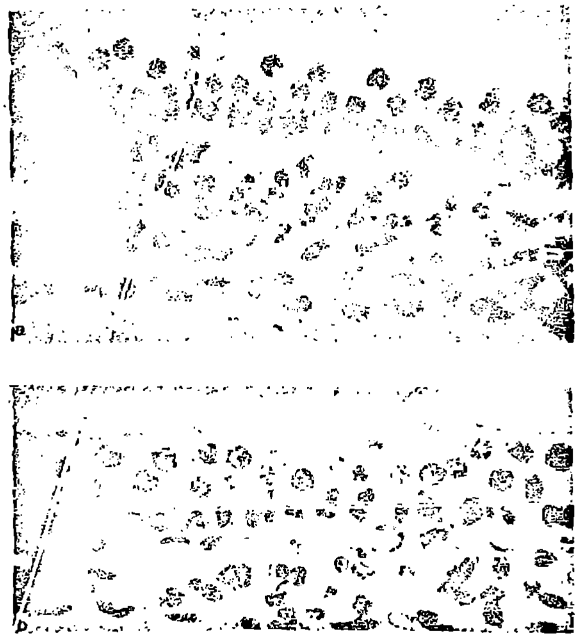


Figure 44. The amount of nucleic acids in receptor cells of the utriculus of a guinea pig.
a — no noise effect; b — under the influence of noise with an level intensity of 120 dB for 3 months. Photomicrography: ocular - 7x, objective - 60x. stained according to Einarson.

The Effect Of Noise On Autonomic Functions And The Cardio-Vascular System

A number of works, especially those of Lehmann, Tamm (1946), Meyer-Delius (1957) and others, deal with the effect of noise on the autonomic nervous system. In the light of data obtained by G. N. Krivitska, this is a completely regularly developing reaction. The opinion is held that the autonomic nervous system reacts only during the noise, and in no more than an hour after it ceases its function is restored. But we must not fail to recognize that pronounced and persistent changes in the functional state of the autonomic nervous system are possible with prolonged noise.

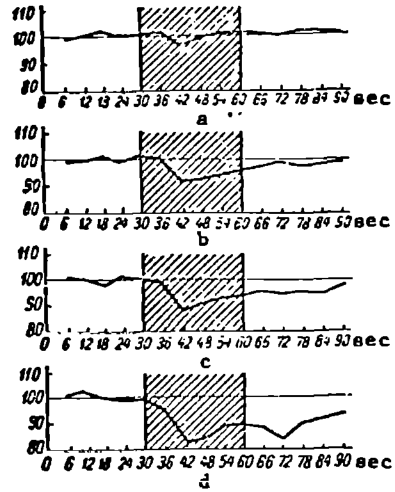


Figure 45. The importance of bands of noise in the intensity of an autonomic reaction (after Meyer-Delius).
a — 3200 Hz; b — third of 3200 Hz. c — octave of 3200 Hz (mean value); d — wide-band noise. Vertically — pulse amplitude in the finger (in %).

Autonomic reactions can be detected even with low intensities of noise (40-70 dB), irregardless of how it is perceived subjectively. Adaptation to noise, as shown by numerous studies, does not appear /138
in autonomic reactions. A noise level of 40-50 dB can cause an autonomic reaction even during sleep. The severity of the reaction depends on the loudness level of the noise, its spectrum and character.

Research shows that when the noise is terminated, damaged autonomic functions are restored slowly. They are preserved longer, the longer the noise or the more unexpectedly it developed.

The most pronounced autonomic reactions are disturbances of peripheral blood circulation in the form of constriction of skin and mucous membrane capillaries. Figure 45 shows the curves obtained by Meyer-Delius, which illustrate blood supply of a finger with various durations of different noise bands (3200-6400 Hz) with an intensity level of 90 dB. The intensity of the autonomic reaction under the effect of various noise frequencies can also be evaluated according to the data of Jansen and Rey (Figure 46).

The diagram shows curves illustrating the amplitude of a pulse wave, depending on the noise band (A), with an intensity level of 87-90 dB. Table 25 gives the character of the stimulus and the amplitude reduction in percentages of the initial value.

In analyzing data illustrating the effect of these noises, it follows that the functional relation between the depth of the reaction and the character of the noise stimulus can be found. As the width of the band of noise increases, the angle between the initial point and the lowest point of the curve becomes increasingly narrower (Table 26). The restoration time of disturbed vascular tone gradually /139
lengthens from 53 seconds with a pure tone to 100 seconds with a wide-band tone.

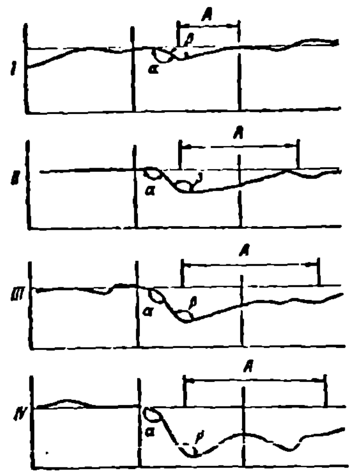


Figure 46. The effect of noise on vascular tone. (after Jansen and Rey).
a — angle formed by the initial point and the greatest deviation;
b — the angle formed by the decay and recovery parts of the wave. Other explanations in text.

Thus, the wider the frequency band, the more pronounced the autonomic reation. A pure tone causes a very slight reaction while third and octave bands and wide-band noise lead to a reaction which increases in severity. It is evident these data indicate that the autonomic reaction is directly proportional to the spectral width of the sound stimulus. The reaction remains stable during the effect of noise.

Jansen and Roy (1962) offer the following explanation of the vascular reactions they observed, depending on the spectral composition of the noise. Nerve fibers from the basilar convolution are stimulated by all sound frequencies; nerve fibers from the upper section of the cochlea are stimulated only by low frequencies. Further analysis of acoustic information is conducted in the five neurons (before the cortex of the brain). However, the connections from neuron to neuron through the fibers do not conduct information farther than a 1:1 relation.

Change in peripheral blood circulation is linearly proportional to the sound pressure, but the frequency of the noise is the determinant for the autonomic reaction. It can be inferred, finally, that autonomic reactions are caused by a psychological factor. However, the relatively long latent period of 6 seconds, which precedes the noise reaction, does not indicate a psychological factor.

A reaction of fright proceeds much more quickly and even with lightening speed. The authors point out that reaction to noise is observed even when it is anticipated by the subject. Ultimately the reaction can also be most intense, when the subject is already accustomed to the noise. /140

TABLE 25

THE EFFECT OF NOISE ON MAXIMUM AMPLITUDE REDUCTION OF A PULSE WAVE*

Character of stimulus	Frequency, Hz	Amplitude of Pulse wave %
Tone	3200	3,5
Third	(2650—3600)	7,3
Octave	(2240—4500)	9,5
Wide-band	(140—8000)	17,6

*Commas represent decimal points.

TABLE 26

DEPENDENCE OF THE ANGLE BETWEEN THE ORIGINAL POINT AND THE LOWEST POINT OF THE CURVE ON INCREASED WIDTH OF THE NOISE BAND

Character of noise	Time of recovery, sec.	Difference, sec.	Angle α	Angle β
Tone	53	24	142	75
Three-octave	77		131	77
Octave	85	8	123	77
Wide band	100	15	115	75

The reaction in the last phase of noise could be considered a result of cumulation. To prove or disprove this, the authors changed the sequence of noises in several tests and obtained the same results.

Another objection might be that autonomic reactions must not be considered a result of external stimuli, but only as a natural regulation of blood circulation. This is contradicted by the greater intensity of the reaction in the noise phase. Subsequently, studies were made of the state of peripheral blood circulation, both in experimental conditions and with workers in noisy shops.

We must point out that not everyone observed a reduction of the blood supply to the skin. S. V. Alevseyev and G. A. Suvorov (1963) found both an average temperature reduction of 1.5° and its increase under the effect of white noise (30-12000 Hz) with an intensity of 80 and 90 dB, with an air temperature of 19-21°. /141

B. A. Krivoglaz and his associates observed thermoasymmetry and sections of the skin with varying temperature; more infrequently they noted distal hypothermia and thermoasymmetry. Of interest is their data regarding the reactivity of vessels to thermal stimuli, indicating the presence of pathological vascular reactions. They will be considered in the section dealing with the clinical characteristics of noise sickness.

There has been comparatively little study of the change in peripheral blood circulation in children during noise. At the same time, there is undoubted interest in a knowledge of its effect, not only on the organism of children but on adolescents as well.

Meyer-Delius (1957), in studying the effect of noise on peripheral blood circulation in children aged 10-14 years, found that they withstand noise better than adults. Mattias and Jansen (1962) examined peripheral blood circulation in children under 11 years of age. They recorded pulse amplitude in the index finger. As a test, they chose a wide-band noise with a loudness level of 1 dB, as well as noise with average frequencies of 8000, 3200 and 800 Hz, and the same loudness. In all the children (47), wide-band noise caused a reduction in the flow of blood to the periphery. Children aged 8-11 years had less reaction than adults; the character of the reaction was the same. The effect of tertiary tones was less. Under the influence of a 8000-cycle tone on children aged 3-6 years, there was no change in the amplitude of the pulse wave; in those aged 6-8 years

there was a slight reaction, and at 8-11 years a distinct decrease of amplitude was noted.

A 3200-tone caused reduced amplitude in children aged 8-11 years; in 6-8-year - olds it was at first strongly reduced, and then increased to normal. There was no reaction in 3-6 year olds. This same effect was also noted with an 800 Hz tone.

To establish autonomic disorders caused by noise, it is necessary, upon examining workers, to determine the condition of the skin, especially in the extremities and mucous membranes of the eye, mouth and nasopharynx. Valuable data can be obtained by recording the dermographic reaction, examining blood circulation in the extremities and by determining pulse rate. It is necessary to study reflexes from hands, feet and abdominal surface, as well as the Khvostek reflex.

Great importance is attributed to a thorough and accurate anamnesis, the general feeling of the subject, length and quality of sleep, how he feels during the day, subjective perception of temperatures and weather. The subject must also be questioned in detail about complaints of headaches, dizziness, possible distortions of visual and vestibular function, pain around the heart. If autonomic functions are disturbed, the reason must be found — is it the noise factor or /142 an individual one, living conditions or other factors accompanying noise.

The problem of noise pathology, in particular possible disorders of the functional state of the cardiovascular system, in an age of vast technological development and its introduction into industry as well as community life is attracting an extensive range of specialists. From the aspect of industrial hygiene and occupational pathology, this problem can only be solved by experimental research and clinical observations.

A. L. Myasnikov (1960) attached significant importance to noise in the genesis of hypertrophic disease. Later, A. A. Andryukin (1961), L. I. Geller (1963) and I. S. Ivatsevich (1963) and others noted hypertonic disease more often among workers in noisy shops.

As it is difficult to find the causes of functional changes in the cardiovascular system in workers under industrial conditions because of the presence of many factors able to disturb it, it is especially important to model industrial

noise in the laboratory.

Many researchers have followed this course. As an example, we present the experimental research of A. M. Volkov (1963) with noise typical of railroad transportation. He noted a tendency toward increased systolic index (calculated according to Fogel'son and Chernogorov) because of the increased frequency of the heart contraction regime; however, this does not always occur. Functional changes in the cardio-vascular system depend not only on the frequency and intensity of noise, but also on its character and time of effect.

We also indicated that the noise factor is often accompanied by other effects able to change the character of the vascular reaction, especially when heightened demands of high temperature or excessive infrared radiation, which occur simultaneously with noise, are made on the thermoregulatory apparatus. Physical work can undoubtedly have an effect. There are observations indicating that in these cases it is difficult to explain changes in the cardiovasuclar system by noise alone. Under the effect of a complex of these factors, peripheral vessels will dilate and not constrict, as is often observed under the effect of noise alone. When arterial pressure is unchanged, less blood will flow, but this is possible only when the stroke volume is less (amount ejected by each heart beat).

Lehmann and Tamm (1956) used a ballistocardiogram to study the condition of /143 blood pressure during and after the effect of tones with a frequency of 800-1600 Hz and 3200-6400 Hz, and an intensity of 90-60 phons. In the majority of subjects, a statistically reliable reduction in the systolic volume of the heart and in the amplitude of arterial pressure was determined. Peripheral resistance to the flow of blood was raised; the pulse rate either was unchanged or was somewhat reduced. These changes were maintained throughout the sound and they developed without any warning of the noise. Sounds with a frequency of 800-1600 Hz and an intensity of 70 phons led to a change in blood circulation only when they caused subjectively unpleasant psychological experiences owing to a certain association. O. P. Shepelin (1961), in experimental conditions, observed varying vascular reactions depending on the character and frequency of the noise. The author noted acclimation to noise with intensity of 70-85 dB, which does not agree with the data of Lehman et al.

There are differing opinions about the dependence of the level of arterial pressure on the duration of noise. Different authors observed the development of

both hypo- and hypertonic conditions. These contradictions are evidently related not only to different intensity and character of the noise studied by individual authors, but also to many other additional factors, as well as individual reactivity; this is responsible for the different direction of a certain deviation from the normal level of blood pressure. There is also a rather large amount of material indicating that hypertonic disease is encountered comparatively often among those working in conditions where they are affected by constant intense noise (A. A. Andryukin, 1961; I. I. Galakhov and A. I. Kachevskaya, 1958; T. A. Orlova, 1958; A. P. Rusinova, L. P. Rodionova, 1968, and others). There are also observations of the hypertensive effect of pulse noises (O. P. Shepelin, 1959; G. A. Suvorov, 1965; M. L. Khaymovich, 1961, and others). Figure 47 presents curves which illustrate changes in the cardiovascular system under the effect of a noise load of 200-400 Hz with a loudness of 90 phons. The upper curve shows the increase of total resistance, which results from vascular constriction. Pulse rate remained unchanged; stroke volume decreased.

S. V. Alekseyev and G. A. Suvorov (1965) in testing the effect of white noise with an intensity of 70,80 and 90 dB (30 minutes-1 hour), using tacho-oscillography and pulsotachometry, found that white noise with an intensity of 90 dB caused an increase in maximum arterial pressure (average of 7 mm), lateral systolic (1 mm) and minimum pressure (12 mm). The frequency of deviations of mean dynamic and stroke pressure (both increase and decrease) was practically the same. The /144
heart beat rate increased 6 beats per minute .

Noise with an intensity of 80 dB also changed arterial pressure and pulse rate. Maximum arterial pressure increased 8 mm (average), and lateral — 9 mm, while minimum pressure decreased 8 mm and stroke pressure — 9 mm. Mean dynamic pressure increased 2 mm. Pulse rate rose 5 beats per minute.

Noise with an intensity of 70 dB caused no changes in the cardio-vascular system.

A. A. Arkad'yevskiy (1960) determined the character of shifts in cardiac activity after the effect of low-frequency noise with intensity of 80, 90 and 100 dB, using the electrocardiographic method. In his tests, the author noted a reduction of maximum pressure and an increase of minimum blood pressure. Thus, data of the author on change in blood pressure were different from those of S. V. Alekseyev and G. A. Suvorov with the effect of white noise. It can be /145

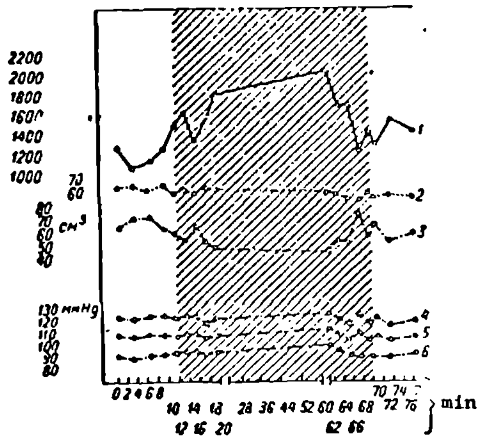


Figure 47. Change in indices of the functional state of the cardio-vasuclar system under the effect of noise.
1 — peripheral resistance;
2 — pulse rate; 3 — stroke volume; 4 — systolic pressure;
5 — mean pressure; 6 — diastolic pressure.

assumed that the difference was determined by the frequency composition of the noise. Pulse rate in the subjects of A. A. Arkad'yevskiy, as well as in those of the above authors, was reduced 6-9 and 14 beats per minute (corresponding to noise intensity of 80, 90 and 100 dB). The author attributes the observed changes in blood pressure to the stimulation of the auditory centers in the subcortical region during prolonged noise, which leads to an inhibition in the autonomic centers and to a change in autonomic functions, primarily hemodynamics.

A change in pulse was observed by E. P. Orlovskaya (1962a,b). After the effect of high-frequency noise with a level of 80 dB for 1 hour 50 minutes, the pulse was slowed down, but after an intensity of 65 and 70 dB, on the other hand, the rate increased.

Pulsed noise has a considerable effect on pulse rete and blood pressure. Unfortunately, there is little experimental research and clinical observations in this area as yet. Undoubtedly change in blood pressure under the effect of pulsed noise and unexpected sounds occurs differently, depending on their character and physical parameters.

In any case, it is well known that stable noises have less effect than pulsed noises. However, the latter can alsr cause both increase and decrease of arterial pressure. O. P. Shepelin observed greater changes in maximum and minimum pressure with pulsed noise than with stable noise of the same parameters.

On experimental research with pulsed noises, we can also note the works of G. A. Suvorova (1968) and E. P. Orlovskaya (1967). They found a significant change in blood pressure and instability in the indices of maximum and minimum blood

pressure. E. P. Orlovskaya noted the interesting fact that change in blood pressure depends on the background against which the noise develops. Aerodynamic noise is a unique pulse noise. In workers who are subjected to it, even before work (in 4.2% of cases) and even more often afterwards (in 14.2%) diastolic hypotonia and asymmetry of vascular tone are observed; a significant difference in maximum blood pressure (over 10 mm) was noted in 55% of the women workers, and 60% after work. Both a 15-20 beat per minute increase in pulse rate and a reduction were noted in these same workers.

A. V. Kadyskin, in determining the bioelectric activity of the brain, at the same time also studied the functional condition of the heart.

The results of the tests of A. V. Kadyskin (1967, 1968), conducted on animals, showed that cardiac activity is at once actively involved in the response reaction /146 to noise. Following actuation of a wide-band stable noise stimulus, a pronounced increase in the number of heart beats was observed. It is important to emphasize that, despite the unidirectionality of the original reaction, its length was considerably greater in animals under the effect of 120 dB noise than under the influence of 90 dB intensity noise.

A definite reaction was clearly revealed in the heart beat in proportion to the effect of noise with an intensidy of 120 dB. A brief rate increase, developing in response to actuation of the noise, rapidly changed to a reduction, which persistently progressed. This caused the rate of heart contractions first rapidly to reach the initial value, while at the end of the experiment the reduction was considerably below the initial level. A similar reaction was revealed distinctly from test to test.

Bradycardia and arrhythmia were quite persistent, being maintained in the aftereffects period even to the next test day. The direction of changes detected in the rate of heart contractions under the influence of 90 dB noise was the same as in the first group of test animals. However, on the next day, the EKG did not differ in frequency from the original. No statistically reliable differences were detected between indices.

Research on humans does not exclude the possibility of individual sensitivity to noise. Therefore, it is necessary to conduct tests on animals.

An important part of the dynamics of the heart in test animals under the influence of noise is analysis of the interrelations between the length of heart cycle phases

and cardiac rhythm. The length of some phases can change significantly when heart rhythm is altered; other phases maintain their length unchanged. This clarifies the interest shown in establishing normal interrelations between the length of phases and the length of the cardiac cycle, which is necessary for correct evaluation of the electrocardiograms obtained before, during, and after the noise. Of especially important interest is a quantitative description of the interdependences of phases of cardiac activity detected in all periods of the experiment. A change in the length of the phases is an indication of disturbance to the functional state of the myocardium, as well as a deterioration in the quality of heart beat regulation.

Cardiac rhythm, of ocurse, is not the only factor determining the length of certain phases of the cardiac cycle normally and under the effect of certain physical factors. This is why A. V. Kadyskin studied changes in the length of systole of the heart (Q-T interval) as well as in the systolic index to evaluate the effect of noise on cardiac activity. /147

The Q-T interval corresponds to the period from the start until the end of stimulation of the ventricles, i.e., the electric systole of the heart. The length of Q-T depends on the duration of the cardiac cycle. As we have already pointed out, data on the systolic index, presented by Ya. I. Fogel'son and I. A. Chernogorov (1957) were used to characterize electric systole at various periods of the experiment. The systolic index is the ratio expressed in percentages of the length of the electric systole, measured by the Q-T interval, to the length of the cardiac cycle:

$$\frac{Q\text{-}T}{R\text{-}R} \cdot 100 = SI.$$

The systolic index, obtained for a given rhythm before the test, was compared with the systolic indices at various periods of noise.

Analysis of the results shows that the length of the electric systole under the effect of noise with an intensity of 120 dB undergoes significant changes, which indicate severe functional changes in the heart muscle of test animals.

Significant extension of the Q-T period was observed in the first 5-7 days of the noise with an intensity of 120 dB; this was observed especially clearly in

the first half of the experiment. However, later the changes observed in the length of the electric systole acquired another aspect. The length of electric systole progressively decreased in proportion to the effect of the noise. Having expressed the ratio of the length of the electric systole discovered in the test (actual) to the length of electric systole at a given frequency normally (standard) in percentages, a significant shortening of the Q-T interval was noted, more than 20%. These data were subjected to statistical analysis, proving them highly reliable. In the aftereffects period, these changes are leveled out, but are not completely restored, which in turn emphasizes the severity of shifts in the function of the myocardium of the test animals.

Evaluating the length of ventricular electric systole during a change in heart beat rate is made easier by calculating the systolic index. If, in the first tests, a slight increase was noted in systolic index, as the experiment continued a marked statistically reliable ($P < 0.01$) reduction of the systolic index was observed, which is illustrated by the graphs below.

Studies conducted analogously in a group of animals subjected to the effect of 90 dB noise showed that the length of the Q-T interval and of the systolic index varied slightly. Analysis of the material did not show sufficient statistical reliability. The data obtained by A. V. Kadyskin indicate that in the first days of the experiment there is a distinct unidirectional reaction, similar to that revealed with 120 dB noise. Also noteworthy is the fact that in both test groups there was a marked reduction of voltage of electrocardiogram waves. However, it must be pointed out, that if EKG potentials, especially the T wave, were rather persistently reduced under the effect of noise with an intensity of 120 dB, with 90 dB noise the electric activity of the heart muscle was rapidly restored immediately after the animals were removed from the noise.

It is known that respiratory reactions are composed partly of various orientation, food, motor and many other unconditioned and conditioned reflexes. A close connection has been established between the respiratory center and various functional systems, and the possibility has been shown of rapid reorganization of its activity depending on the effect of the internal or external medium.

Comparison of the dynamics of changes in cardiac and respiratory function is unnecessary, as they are both various aspects of the same function. The /149

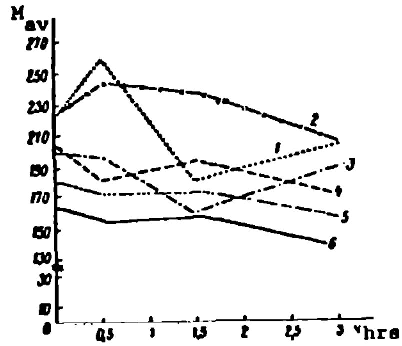


Figure 48. Change in heart beat rate under the influence of noise (120 dB)
Days of experiment: 1 — first; 2 — second; 3 — fifth; 4 — sixteenth; 5 — twenty-sixth; 6 — thirty-sixth.

accumulation of regulatory effects will ultimately produce the same result: the most optimum ratio between level of activity of these systems and specific requirements of the medium. This is why revealing changes which occur in the respiratory function under the effect of noises of various parameters is important both theoretically and practically. This becomes especially clear if we consider that the respiratory function is responsible for gas exchange which is the basic link of metabolism.

Changes in the respiratory function were noted by L. F. Fasler (1928), L. Ye. Milkov (1963a) and others.

The tests of A. V. Kadyskin found that wide-band stable noise caused certain changes in frequency, rhythm, and type of respiratory movement.

Actuation of noise with intensity of 90 and 120 dB caused a sharp increase in the respiratory rate; the data show that it is more pronounced with 120 dB noise. It must be pointed out that in animals, besides the increased respiratory rate, the amplitude of respiratory movements also increased. This probably indicated that the noises being used at a given stage of the experiment stimulate the activity of the respiratory center, and increase its functional effort. However, further changes in respiration in both experimental groups proceed differently, which could have been attributed to differences in the intensity of noise used.

The results of statistical analysis of the frequency of respiratory movements with the effect of noises with a level of intensity of 90 and 120 dB are given in the form of graphs (Figure 49). With noise of 120 dB, a high degree of statistical reliability was seen in the change in respiration rate in all periods of the experiment. There was an almost complete lack of statistical reliability obtained from animals subjected to 90 dB noise.

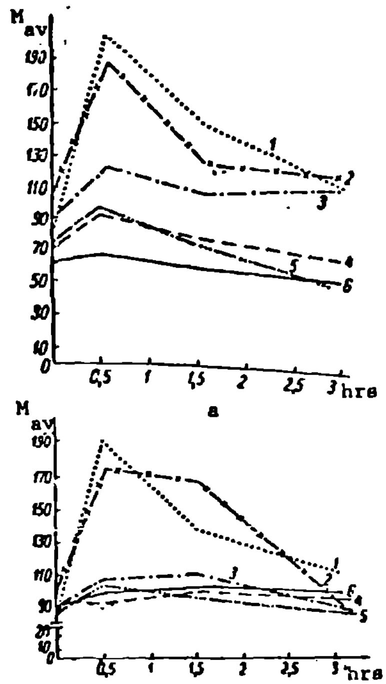


Figure 49. Change in respiratory rate under the influence of noise with an intensity of 120 (a) and 90 (b) dB. Legend same as Figure 48.

Under the effect of 120 dB noise, as the experiment continued the rate of respiratory movements significantly decreased. By the end of the experiment, the respiration rate had been reduced nearly one half. Also noteworthy is the fact that changes in the respiratory system are not transitory, but persist to a certain extent. This is indicated by the preservation of a progressive reduction of the respiratory rate, not only during the aftereffects period, but also to the next test day.

As can be seen from these data, the respiratory rate is also significantly reduced in the initial data, i.e., before actuation of the noise; changes progress as the experiment continues, as well as from test to test. It can also be noted that actuation of the noise caused a new reaction in the respiration. If, at the start of the experiment the amplitude of respiratory movements is increased in the test groups along with the respiratory rate, subsequently there are essential differences in the reactions of both experimental groups of animals. Starting with the 5-7th day, under the effect of 120 dB noise, despite the reduced number of respiratory movements, there was a significant reduction in the respiration amplitude.

By the end of the experiment, the amplitude of respiratory movements in the first experimental group was almost three times lower in comparison with the original data.

Regarding changes in the respiratory function under the effect of noise with an intensity of 90 dB, tests on animals showed that as the experiment progressed a tendency toward increased respiratory rate was maintained during each test, and a

reduction of respiration by the end of the experiment. However, after deactivation of the noise, the rate of respiratory movements was rapidly restored and the amplitude of respiratory movements varied slightly. We must note that basically respiration under 90 dB noise 30-60 minutes after the start of the test did not differ from background data. There was no disturbance of respiratory rhythm.

No statistically reliable change in the respiratory rate could be detected in this group of experimental animals. /151

Data about the types of respiration produced in animals with noise of 120 dB are especially interesting. It was pointed out above that noise caused not only increased rhythm of respiratory movements. but a sharp increase in amplitude as well. Even in the first days of the experiment, especially at the end of each test, periodic respiration was noted after such intense activity of the respiratory center. These phenomena were progressive, and as the experiment continued still more severe and more pronounced disorders of the respiratory function began to develop against a background of high-power noise. Following pronounced functional strain of the respiratory center, wavy respiration developed, and later — breathing resembling the complete and incomplete rhythm of Cheyne-Stokes respiration.

However, this pattern was not stable: periods of wavy respiration alternated with even breathing resembling periodic Cheyne-Stokes respiration. It can also be noted that the relatively long periods of intense respiration with a high amplitude alternated with shorter periods, but with a low respiration amplitude. The changes in the functional ability of the respiratory center under the effect of noise, noted above, clearly progressed as the test continued and occupied an ever-increasing part of the recording.

The cyclic character of respiratory reactions indicated, evidently, that under the effect of intense noise, the respiratory center switches first to a higher, then to a lower level of activity. Experimental data have helped detect various types of respiration. The types of periodic respiration detected which develop under the effect of intense and prolonged noise, appearing with a change in the relative depth and frequency of respiration, are evidently due to variations in the tone of respiratory muscles and the interaction of intensification and weakening waves. We must point out that, as the experiment continued, various types of pathological respiration developed most often in the first half of each test and, having developed, alternated with each other as well as with periods of even breathing. The alternation of frequent and deep breathing with periodic respiration, as well as the progressive reduction of respiratory movements, their replacement by even movements, etc., once more demonstrated the broad

functional potential of the respiratory center. However, removing the animal from the effects of the noise restored even breathing, and correspondingly, increased the amplitude of the respiratory movement.

The Effect Of Noise On the Emotional State Of Man And His Working Capacity

With respect to the emotional state of the organism which determines human behavior during long and short effects of noise, there are more investigations /152 than established facts. This is not surprising, if we consider not only the various parameters and character of noise, but also the individual reactivity of humans to this stimulus and the often great complexity of the environment in which human activity occurs. We can hardly ignore the effect of noise on the psyche during rest.

The opinion is held that noise can act purely psychologically ("unpleasant" sensation, a feeling of annoyance, etc.), reduce working capacity and cause a number of objective physiological reactions.

In this direction, some interesting data have been obtained by Rosenblieth (1957), Kryter, Ward, Miller (1966). The latter conducted research in the laboratory with his students. If mental work must be performed, the annoying effect of noise is seen very quickly. Miller, as well as the coworkers of the Department of Industrial Hygiene of the LSGMI, pointed out the dependence of subjective "unpleasantness" of noise, developing while performing tasks under the strain of mental activity.

Broadbent (1958) feels that there are several sources of information which will give an idea of the reasons for the irritating effect of noise. The first is observation of those instances where there is an obvious effect or considerable irritation from noise. However, although this method has its positive aspects, it cannot be considered sufficiently conclusive. Therefore, the broad use of the experimental-laboratory method of study is suggested. Broadbent presents data on the relation between the loudness level of noise, unpleasant sensations, and conditions in which people find themselves. For example, the loudness of household noise coming from neighboring apartments is only 60 dB. However, its irritating effect is extremely high, as are the high number of complaints.

In the overwhelming majority of shops the loudness level of noise is much greater (most often 90 dB), but nevertheless, it does not have an irritating effect. Evidently, the reason is the presence of an operative dominant element and the surrounding situation. But neither must we ignore the varying sensitivity and reactivity of individual persons to the noise stimulus — the special sensitivity of some and the low sensitivity of others. Therefore, an undoubtedly important problem is developing effective tests which might help to pin point workers who are extremely sensitive to noise in noisy shops. /153

In rooms where people perform mental work, the same noise causes irritation and an unbearably unpleasant sensation. Therefore, it is difficult to establish criteria for a general level of loudness which will always have an irritating effect. The latter is closely connected with the fact that man cannot distinguish ordinary conversational speech, as well as the fact that noise interrupts production activity, reading, etc. The sensation of "unpleasantness" depends on the intensity and spectral composition of the noise. Large vibrations also cause more "unpleasantness" than if they were smaller. They are percieved as very unpleasant tones, irregularly pulsating. It must be recognized that the most conplaints about noise irritation are due primarily to the physical data of the latter. Sounds or high-frequency noises (1500 Hz or higher) have a more irritating effect than low-frequency noises of the same intensity. However, there are observations which indicate that low sounds (about 100 Hz) also are more irritating than noise with a spectral composition arranged closer to the center of the voice spectrum. Its extreme frequencies irritate more than the middle frequencies (Pollack, 1952). Unfortunately, this range of low frequencies has attracted little attention. It is here where the greater number of complaints against the irritating effect of noise fall (Ye. Ts. Andreyeva-Galanina).

Yu. S. Karyukayev presents interesting data on the number of complaints about irritation among the large group of workers he examined, who were subjected to the effect of medium - and high-frequency noise with an intensity level of 97-116 dB. When the worker had spent less than 5 years on the job, the complaint rate was 10%; those working from 6-10 years — 28%; 11-15 years — 65%; and over 15 years — 94%. There is the opinion that noise in which the greatest energy falls on individual tones is more irritating than that where it is evenly distributed.

Miller noted the pronounced irritating effect on his audience of a wide spectrum of noise. He pointed out that their perception did not remain constant

but changed, depending on the background, and vice versa. E. P. Orlovskaya (1967) established the background value in her experiments with impulse noises.

Discontinuous impulse noise has a greater stimulating effect, especially if the sounds vary in their intensity and frequency. In this connection, the assumption is made that here the change of frequencies is not as important as that of intensity. In any case, long-acting impulse noise causes more irritation than stable. The opinion is also expressed that strictly periodic but not sinusoidal noise also has a great stimulating effect — for example, the noise of automobile horns or human screams. Miller established that, if the length of certain tones of noise in a sequence of sounds is greater than in others, this noise becomes more irritating than stable noise. The irritating effect increases if there are quiet pauses in the noise. In spite of the undoubtedly interesting data regarding the character of noise, its frequency composition and intensity and other characteristics, the reasons for its irritating effect are still far from being resolved. Broadbent (1958) feels that sound which changes location can be more irritating than that which remains stationary. If the noise source remains constant, it can be adapted to more quickly and its irritating effect becomes insignificant — another kind of reaction develops.

When the source of a noise has a certain location, the position of this source in relation to man becomes important. They should not coincide.

<u>The effect of noise on working capacity.</u> Holstead (1958), studying the working capacity of people under the noise of an airplane engine, found that in these conditions their working capacity was reduced, which he established by having them perform certain tasks.

The experimental research of S. V. Alekseyev and G. A. Suvorov using the proof method (according to the tables of Anfimov) showed a definite dependence of mental working capacity on the intensity of white noise. At an intensity of 70 dB, it was reduced 3.8%; at 80 dB — 5.2%, and at 90 dB — 12.2%.

Broadbent gives the results of research with the noise of weaving machines at an intensity level of 96 dB. Some of the subjects wore ear phones, other did not. Working capacity was lower in the second group than in the first. The author also established that discontinuous noises interferred with mental work more than stable . Analogous effects were also observed by G. A. Suvorov (1958).

TABLE 27

REDUCTION OF CONCENTRATION OF ATTENTION (IN %)
IN COMPARISON WITH INITIAL VALUE*

Intensity, dB	Reduction of concentration of attention			
	Initial values	After 30 min.	After 60 min.	After 120 min.
100	31,2	23,2	20,7	15,6
90	18,9	18,2	15,8	10,4
80	15,1	14,6	10,2	8,1
70	9,5	10,4	5,8	5,1
60	5,7	5,0	1,7	1,0

*Commas represent decimal points.

There is a large amount of research on the reduction of physical work capacity. According to the data of S. S. Vishnevska, S. I. Gorshkov (1960) and others, intense noise reduces capacity of working and increases the number of errors.

Human activity is closely connected with concentration of attention. Reduction of the latter must, without doubt, also affect the productivity of work, i.e. working capacity, whether that work is physical or mental. /155

Z. F. Panayotti (1963) studied the effect of medium-frequency noise with an intensity of 60, 70, 80, 90, and 100 dB on subjects in a soundproof chamber for 2 hours. She noted two facts concerning concentration of attention: first — that it depends on the intensity of the noise; second — that it is most sharply altered immediately after the activation of noise. Later, as the effect of noise continues, concentration of attention increases.

Table 27 shows the change in attention under the effect of noise of varying intensity and effective time. Corresponding data were also obtained by the author with respect to the distribution and switching of attention.

Her data imply that noise of medium-frequency with a level of intensity of 80-100 dB can undoubtedly lead to a reduction of productive work and attention, which is especially dangerous in those industries where there are moving objects and traumatism is possible. M. A. Chuchumov (1965) noted that noise can lead to increased traumatism.

CHAPTER IV

THE EFFECT OF NOISE ON THE FUNCTIONAL STATE OF THE CENTRAL NERVOUS SYSTEM

We now know that the stronger the noise stimulus and the longer its effect, the greater damage it will cause in the organism. The frequency composition of /156 the noise, the intensity and time of its action, individual perceptiveness and other attendent industrial and daily factors play an important role in the character of developing damage.

A large number of studies, conducted under industrial, clinical and experimental conditions, have been directed toward finding the mechanisms of occupational deafness diagnosing early damage to the organ of hearing, determining auditory sensitivity during the effect of various occupational noises and developing means of prevention.

Much later, several researchers turned their attention to the fact that during noise, the functional state of the central nervous system is disturbed first. Nevertheless, this question has not received sufficient study in works dealing with the effect of noise on the organism.

Determining the role of the central nervous system will undoubtedly reveal the mechanism of pathological shifts observed in the organism during the effect of noise and make it possible to justify and, at the same time, undertake preventive steps against the development of noise pathology.

As is known, up to a certain point, increasing the intensity of an external

agent causes intensification (excitation) of corresponding activity of the organism. But functional resources of vital systems are not unlimited, and extremely strong or extremely long stimulation causes maximum inhibition, protecting the reactive structures from exhaustion or death. The most striking feature of maximum inhibition is the distortion of reactions to strong stimulations, resulting in compensatory, paradoxical, ultraparadoxical, and inhibitory stages (N. Ye. Vvedenskiy). There is every basis for assuming that maximum inhibition is connected with severe, though reversible, shifts in cellular cytoplasm (D. N. Nasonov).

P. V. Simonov (1966) advances the hypothesis of discontinuous inhibition, /157 indicating that the force and length of stimulation does not always exceed the functional resources of the system, the limit of its excitation, or the limit of its working capacity. And at that moment stimulation is replaced not by maximum inhibition, but by another inhibitory state, different from the maximum. This is primarily expressed by the preservation of reactions to strong stimuli with depression of reactions to weak stimuli.

Considering that a noise stimulus has extremely varied physical characteristics, various shifts might also be expected to develop in the central nervous system; this is substantiated by literature data and our research.

There is the opinion that fatigue is not the same in various sections of the nervous system during intense noise. K. Shreder (1958) speaks of stronger fatigue during a complex reflex and the pronounced increase in susceptibility to fatigue of complex coordination centers and, later, the cerebral cortex. The more complex and higher the zones of the central nervous system involved in work activity, the more they suffer from noise.

With the effect of noise, many authors have observed an increase of the latent period of conditioned motor reaction, a reduction or disappearance of conditioned reflexes, differentiation disturbances, and sometimes pathological intensification and slight stagnation of the irritable process (L. V. Krushinskiy, L. N. Molodkina, D. A. Fless, 1950). Cases of loss of consciousness, development of epileptoid convulsions and paralysis during the effect of severe noise have been described by Tomatis (1959), Symanski (1959), Kreyndler and others. However, Titesa (1965), on the basis of his own and literature data, feels that musicogenic epilepsy is encountered quite rarely (a little more than 70 cases are described). In such

patients, epileptic convulsions are caused exclusively by music, regardless of their musical culture. In these cases, elementary noises are still not the cause of convulsions, which are often observed with the sounds of a certain instrument or melody. S. N. Davidenkov (1960) described cases of epileptic convulsion developing in response to the same aria.

The pathogenesis of sonogenic epilepsy is still not clear. L. V. Krushinskiy (1950), in an experimental study of the mechanisms of convulsions, conducted tests on rats in a chamber to which a 80-130 dB sound, composed of high and low frequencies, was fed. Motor excitation was noted in the rats in response to the sound stimulus, often ending in convulsions. After the convulsion ended, a stuporous condition appeared, alternating with complete areflexia. L. N. Molodkina (1956) /158 feels that motor disturbances during convulsions are the result of exhaustion and weakening of the inhibitory process.

The comparative genetic research of M. S. Alekseyeva, V. I. Yelkina and V. K. Fedorova (1964), studying the rate of development and alteration of conditioned reflexes in rats sensitive to the effect of a sound stimulus and rats of the Wister line, showed that the mobility of nerve processes is an inherited trait of the nervous system. The authors also determined a statistically reliable higher mobility of nerve processes in rats which are highly sensitive to the effect of sound. It was noted that the offspring of animals in which convulsions always developed in response to a sound stimulus had a much higher percentage of susceptibility to convulsion.

S. V. Alekseyev and G. A. Suvorov (1967), studying under experimental conditions the effect of noise of various parameters on the functional state of the central nervous system of man, established that just being in an experimental situation has an important effect on the organism (Table 28). Being in a soundproof chamber for 3-4 hours causes fatigue of the nervous system, which is evident from the lengthening of the absolute values of the latent period of the visuomotor reaction to strong and weak stimuli (19.1 and 16.6 msec. respectively). At the same time, the strength of the effector response is decreased (an average of 14%) and force ratios are disturbed. The number of normal force ratios (the dependence of the motor effect on the intensity of the conditioned stimulus) is reduced by 4.5%. The appearance of phase conditions indicates disturbance to the basic nerve processes. With prolongation of the experiment to 2 hours, changes become less pronounced

TABLE 28

EFFECT OF EXPERIMENTAL CONDITIONS ON THE SUBJECTS WITHOUT NOISE*

Exposure, hrs.	Before the start of the test							After the test ended						
	Force ratios of reactions to light and sound			Intensity of effector response to light stimulus, relative units		Latent period of response to light stimulus, msec.		Force ratios of reactions to light and sound			Intensity of effector response to light stimulus, relative units		Latent period of response to light stimulus, msec	
	total determinations	of normal abs.	of normal %	strong stimulus	weak stimulus	strong stimulus	weak stimulus	total determinations	of normal abs.	of normal %	strong stimulus	weak stimulus	strong stimulus	weak stimulus
0,5	360	326	90,5	78,3	52,2	183,5	209,0	360	352	97,7	85,4	58,0	186,0	206,4
1	360	326	90,5	75,0	43,4	182,1	211,6	360	326	90,5	75,0	40,2	185,9	212,3
2	360	324	90,0	76,6	45,2	185,0	211,7	360	320	88,8	68,7	40,9	185,4	250,0
3	360	328	91,1	77,3	51,2	173,8	214,5	360	312	86,6	66,1	43,8	198,9	234,1

TABLE 29

EFFECT OF WHITE NOISE OF VARYING INTENSITY ON THE CENTRAL NERVOUS SYSTEM*

Intensity of noise with 1 hour of exposure, dB	Before the start of the test							After the test ended						
	Force ratios of reactions to light and sound			Intensity of effector response to light stimulus, rel. un.		Latent period of response to light stimulus, msec.		Force ratios of reactions to light and sound			Intensity of effector response to light stimulus, rel. un.		Latent period of response to light stimulus, msec.	
	total determinations	of normal abs.	of normal %	strong stimulus	weak stimulus	strong stimulus	weak stimulus	total determinations	of normal abs.	of normal %	Strong stimulus	weak stimulus	strong stimulus	weak stimulus
90	360	326	90,8	78,2	45,3	176,0	213,2	360	274	76,1	48,1	30,4	198,0	258,2
80	360	328	91,1	82,7	44,2	182,5	212,6	360	298	82,7	65,4	35,0	200,8	241,6
70	360	328	91,1	75,0	43,4	182,1	211,6	360	324	90,2	75,0	40,2	165,9	212,3

* Commas represent decimal points.

and appear basically in the form of a slight reduction in the intensity of response reactions to strong and weak stimuli (10.4 and 11.1%). The authors established that 1- hour exposure does not cause pronounced changes in these functions, while exposure for 30 minutes causes a slight increase in the latent period as well as in the absolute values of motor reactions (9 and 11%) to strong and weak stimuli in comparison with the original indices. At the same time a slight increase in the number of normal force ratios is noted. Changes in the motor reflex with 30 minutes of exposure can probably be considered as a slight disturbance in the equilibrium of cortical processes aimed at intensifying the stimulation process.

Studying the effect of a noise stimulus (white noise) for 60 minutes, the authors established that this noise with an intensity of 90 dB causes pronounced shifts in the visuomotor reaction (Table 29). Variational statistical analysis of these data shows a reliable reduction of the intensity of the effector response of 30.1 relative units to strong stimuli, and 14.9 relative units to weak ones. The latent period of the visuomotor reaction increased 20 and 45 msec., respectively. The number of normal force ratios decreased an average of 14.4% from the initial value. This disturbance of true ratios between the force of the effector response and the intensity of the stimulus was seen in the form of compensatory and paradoxical phases. The latter is only noted after the effect of noise. Under the influence of a noise stimulus with an intensity level of 80 dB, an average reduction of 14.3 rel. units in the intensity of the response reaction to strong stimuli is primarily noted, and 9.2 rel. units to weak light stimuli. The latent period of the conditioned motor response is also increased an average of 18.8 msec in response to strong light stimuli, and 29.0 msec to weak stimuli. The number of normal force ratios after the effect of sound is reduced, but not as much as was observed with 90 dB. After the effect of wide-band noise with an even spectral density of sound intensity, at a level of 80 dB, an average decrease of 8.4% was noted in normal force ratios from the original values, which primarily appears in the form of compensatory phases. After an hour's exposure with intensity at 70 dB, the authors note no important changes in the conditioned motor reaction. /160

Studying the effect of noise with maximum sound energy at frequencies of 300, 500 and 700 Hz and intensity of 90 and 80 dB on the functional state of the central nervous system, S. V. Alekseyev (1965) observed a change (Figure 50). With the maximum of sound energy at 700 Hz and the intensity level at 90 dB, the author found a 48% reduction in the intensity of the reaction, and with the sound energy maximum at 300 and 500 Hz, a 29.1 and 37% reduction, respectively, was noted in

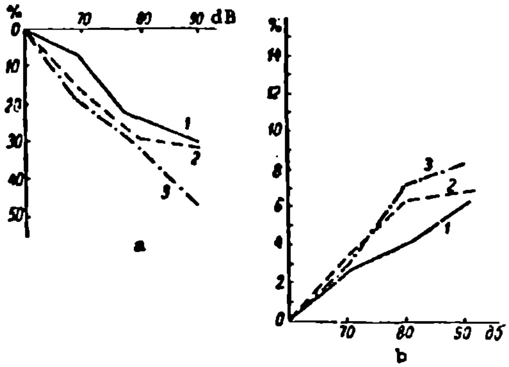


Figure 50. Change in the intensity and time of the latent period of the visuomotor response to a light stimulus after the effect of a medium-frequency noise of various parameters.
After noise with maximum of sound energy at frequency: 1 — 300 Hz; 2 — 500 Hz; 3 — 700 Hz.
Horizontally — level of intensity noise; vertically — change in the intensity (a) and time of the latent period of the response (b) in relation to the pre-noise level.

the intensity of the reaction. After one hour exposure to noise with an intensity of 80 dB and maximum sound energy corresponding to frequencies of 300, 500 and 700 Hz, the intensity of the reaction was reduced 14.5, 26, and 33.8%, respectively. The latent period of the visuomotor response lengthened when the intensity level of the noise was 90 dB: it was most pronounced with the sound energy maximum at 700 Hz (before the noise, 179 ± 1.2 msec; after the noise, 199 ± 1.5 msec) and least with the maximum of sound energy at a frequency of 300 Hz (before the noise, 178 ± 1.4; after the noise, 190 ± 1.6 msec). After being exposed to noise with an intensity /161 level of 80 dB for an hour, the latent period of the visuomotor response lengthened. It was also most pronounced with the maximum of sound energy at a frequency of 700 Hz (before the noise, 175 ± 1.5 msec; after the noise, 187 ± 1.4 msec) and least at a frequnecy of 300 Hz (before the noise, 177 ± 1.4 msec; after the noise, 184 ± 1.7 msec). Noise with an intensity level 70 dB reduced the force of the effector response, with the sound energy maximum at frequencies of 300, 500 and 700 Hz corresponding to 4.0, 14.5 and 17.9%.

The latent period of tho visuomotor response to a strong stimulus after the effect of noise with a maximum sound energy in frequencies of 500 and 700 Hz increased correspondingly 5 msec (before noise, 177 ± 1.5 msec; after noise, 182 ± 2.0 msec) and 8 msec (176 ± 1.4 and 184 ±1.5 msec).

The severity of changes in the intensity and time of the latent period of the visuomotor response to a weak stimulus was found to be in direct correlation with its changes for a strong stimulus.

Studying the effect of octave noise bands on the functional state of the

central nervous system, S. V. Alekseyev found that the most pronounced changes in the force of the effector response were with 90 dB noise. In particular, after /162 the effect of the 300-600 Hz octave band a 27% reduction was noted; 40.3% after 600-1200 Hz, and 42.3% after 1200-2400 Hz. After noise with an intensity of 80 dB, the most pronounced changes also appear with the effect of the 1200-2400 Hz band. Intensities of the effector response are reduced 32.1%. Noise with an intensity of 70 dB reduced the force of the reaction after exposure to the 300-600 Hz band 8.5%, 15.4% after 600-1200 Hz, and 19.5% after 1200-2400 Hz.

The results of a study of the latent period of the visuomotor response, analyzed by S. V. Alekseyev, showed that the degree of changes also depends on the intensity and the frequency composition of the noise. Thus, the most pronounced changes are noted during the effect of noise in the 1200-2400 Hz octave band and an intensity level of 90 dB; the latent period of the visuomotor response to a strong light in this case increased by 11.6%. The latent period of the visuomotor response to a strong light after the effect of 70 dB noise lengthened 1.3% under the effect of octave noise in the 300-600 Hz band (statistically unreliable), 3% after 600-1200 Hz , and 4.8% after 1200-2400 Hz. In studying the intensity and time of the latent period of the visuomotor response to a weak light, it was discovered that their changes after noise are similar to data obtained in studying the visuomotor response to a strong stimulus. The effect of an hour's exposure to octave bands of noise also caused a reduction of normal force ratios, whose severity depended on parameters of the noise (Table 30).

Research studying the effect of noise of various octave bands on the nervous system of man was conducted by T. A. Orlova (1965).

The author studied the effect on the functional state of the central nervous system of individual octave bands of noise and total wide-band noise with levels corresponding to the maximum permissible curve with an index of 85. Twenty obviously healthy young subjects spent 2-3 hours in an acoustic chamber. Under the effect of wide-band PS-85 noise, in all those examined in the first signal system the disparity between the physical force of the conditioned signal and the responding conditioned reflex motor response increased: before the effect of noise, phases of normal ratios were pronounced in 75% of tests conducted, and compensatory and paradoxical phases, i.e., inadequate reactions — in 25% of the tests. After the noise, the number of inadequate reactions doubled and reached 50%. The latter, in the opinion of the author, indicates that 2 hours of noise causes protective

TABLE 30

FREQUENCY OF DEVIATIONS FROM NORMAL FORCE RATIOS IN REACTIONS TO LIGHT AND SOUND STIMULI UNDER THE EFFECT OF OCTAVE NOISE BANDS*

/163

Octave band, Hz	Intensity level of noise dB	Before exposure to noise			After exposure to noise		
		Reactions to light and sound normal			Reactions to light and sound normal		
		Total number	Abs.	%	Total Number	Abs.	%
300—600	90	360	328	91,1	360	306	85,5
	80	360	330	91,6	360	308	85,5
	70	360	328	91,1	360	316	87,7
600—1200	90	360	326	91,0	360	296	82,2
	80	360	330	91,6	360	302	83,8
	70	360	324	90,0	360	310	86,1
1200—2400	90	360	326	91,0	360	284	78,8
	80	360	326	91,0	360	296	82,2
	70	360	328	91,1	360	310	86,1

*Commas represent decimal points.

inhibition in the cerebral cortex. More severe shifts in the dynamics of higher nervous activity were observed in the subjects: in 50%, the contracting ability of the cerebral cortex was weakened; in 30%, difficulty was noted in making an inhibited connection, in 20% — in making a positive one. In 30% of those examined, a disturbance was noted in the mobility of nerve processes, mostly intensification of inertia of the stimulation process.

On the basis of experiments and industrial research, it can be concluded that wide-band noise with PS-85 levels causes unfavorable shifts in the organism.

As was noted earlier, unlike stable noise, the effect on the organism of impulse noise is determined by specific time parameters, as well as intensity and spectral composition.

The research conducted by G. A. Suvorov (1968) with an impulse sequence from 0.5 to 25.0 per second (average intensity 80 dB, 1:1 ratio of length to pause)

showed that the severity and character of the shifts in the central nervous system clearly depend on the pulse repetition rate. Noise with low (0.5-1 Hz) and high (about 15 Hz) pulse repetition rates causes greater shifts than stable noise which is equal in energy and loudness. Significant changes are observed at a recurrence rate of 0.5 pps with a 1000 msec interval between the pulses, when a decrease of 39.1% is /164 noted in the force of the effector response of the visuomotor response, an increase of 25.0% in its latent period, 13% reduction in the number of normal force ratios (paradoxical phases) and concentration of attention.

Increase of the pulse recurrence frequency to 3.4 pps and then to 8.4 per second causes a definitely weakened unfavorable effect of noise. These changes in the physiological functions of the organism, and primarily in the central nervous system, the author attributes to the central mechanism of infrequent sound stimuli. With increase of the pulse recurrence frequency, this mechanism loses its importance in the pathogenesis of these changes.

With a recurrence frequency of 16.7 pps (30 minute interval between pulses [sic]) changes become very pronounced; however, in higher nervous activity, the shifts are less important than during infrequent stimulations. In this connection, it was of interest to determine the threshold pulse frequency, at which the effect on the organism of noise pulses does not differ from stable noise of equal energy. A study of the effect of pulse noise with a frequency of 6.7, 25.0, 30.0, 33.4 per second (average intensity 80 dB, 1:1 ratio of length to pause) on the functional state of the central nervous system showed that, during the influence of pulse noise with a frequency of 16.7 pps, a reduction of 19.9% is noted in the intensity of the reaction to strong light stimuli, and a 19.4% lengthening of the latent period of the response. Disturbed force ratios usually appear in the form of compensatory phases. The number of normal force ratios is reduced 13.4%.

Less pronounced changes are caused by noise with a pulse frequency of 25.0 per second; when the intensity of the response is reduced 17.7%, the latent period increases 16.1%, and the number of normal force ratios is reduced 13.4%.

Less pronounced changes are caused by noise with a pulse frequency of 25.0 per second; when the intensity of the response is reduced 17.7%, the latent period is increased 16.1%, and the number of normal force ratios is reduced 10.5% [sic]. With the subsequent increase of the recurrence frequency to 30 pps, the effect of

noise on the central nervous system becomes identical to that of stable noise; no reliable tendency toward weakening the effect of pulse noise is noted with a further increase of the pulse frequency to 33.4 per second. Thus, the intensity of the effector response of the reaction is reduced 16.8% under the effect of noise with a frequency of 30 pps, and 17.0% with noise of 33.4 pps. The latent period of the response is lengthened 11.9 and 10.5% respectively, but the number /165
of normal force ratios is reduced 9.1 and 8.8% (Table 31).

Pulse recurrence frequency is closely connected with duration; this is the basis for studying the effect on the organism of noise, depending on the duration of pulses.

The research of G. A. Suvorov suggests that not only auditory perception, but the effect of the biological activity of brief pulses lasting 100-200 msec is also proportional to their energy.

Thus, reducing the length of pulses from 100 to 10 msec (frequency recurrence 0.5 pps, maintaining their average intensity of 77 dB) does not reduce the activity of the noise stimulus. The effect of noise is expressed by the reduction of the latent period of the visuomotor response by 20.5 msec, and a decrease of 15.4 relative units in its intensity and 10.3% in the number of normal force ratios. Only when the length of pulses is increased to 1000 msec is the severity of the effect of noise on the organism markedly increased (Table 32).

From this, it can be concluded that: the shorter the signal or sound pulse in a range from several milliseconds to 2-3 seconds, the greater must be the level of its intensity so that it may be heard or cause a biological effect. Thus, a noise pulse lasting 1 msec must be heard at 22-24 dB in comparison with a signal lasting 1 second. Rapid, frequently recurring emissions of sound pressure (of moderate intensity) are not particularly important for calculating the integral properties of the human "auditory" analysor, as they are perceived as fused. This is because the auditory sensation, as well as the biological effect of short pulses, is proportional to their energy. These data can serve as a basis for /167
establishing a definite integration constant in analyzing unstable noise. Too high an integration value can hide from the researcher steep drops of sound pressure, which, in many respects, determine the biological effect of unstable noise. On the other hand, a very short integration time can complicate the picture of the noise process. In this case, emissions or fluctuations appear in the envelope which are

TABLE 31

FREQUENCY OF DEVIATIONS FROM NORMAL FORCE RATIOS IN REACTIONS TO LIGHT AND SOUND STIMULI UNDER THE EFFECT OF PULSE AND STABLE NOISES*

	Before exposure to noise			After exposure to noise		
Noise with average intensity of 80 dB, (pulse of 83 dB). Frequency pps	total reaction to light and sound	normal	% devi-ations	total reaction to light and sound	normal	% devi-ations
16,7	360	328	8,9	360	280	22,3
25,0	360	326	5,5	360	288	20,0
30,0	360	324	10,0	360	291	19,2
33,4	360	330	8,4	360	296	17,8
Stable white noise below 80 dB	360	328	8,9	360	298	17,3

*Commas represent decimal points.

not essential, as they are perceived as fused. Such attempts have already been made; Niese (1963) suggested an integration constant of 23 msec. True, the author equates pulse noises with stable ones in subjectively evaluating their loudness, which, of course, still does not indicate the biological effect with concealed drops of the envelope.

Ye. Ts. Andreyeva-Galanina and G. A. Suvorov (1968) think it is possible, on the basis of literature data and their own data, to establish a time constant of integration, and they suggest using the averaging time of 10 msec as the interval. The selection of a definite constant as the averaging interval to express instantaneous power, i.e. the instantaneous mean square value of sound pressure, is dictated by the necessity to preserve only the most essential characteristics of the time structure of the noise, important from the point of view of auditory perception and the effect of unstable noise on the organism.

In studying the effect of impulse noise on the human organism, it is important to consider the role of the leading edge of pulse rise. The research conducted by G. A. Suvorov showed that the biological effect of pulse noise

TABLE 32

THE EFFECT OF PULSED AND STABLE NOISE ON THE CENTRAL NERVOUS SYSTEM

Medium intensity noise 77 dB	Before the start of the test							After the test ended						
	force ratios of reactions to light and sound			intensity of effector response to a light stimulus, rel. units		latent period of reactions to a light stimulus, msec		force ratios of reactions to light & sound			intensity of effector response to a light stimulus, relative units		latent period of reactions to a light stimulus, msec	
	all determinations	of normal		strong	weak	strong	weak	all determinations	of usual		strong	weak	strong	weak
		abs.	%	stimuli		stimulus			abs.	%	stimulus		stimulus	
Stable	360	325	90.3	76.7	46.1	185.1	211.8	360	295	81.9	64.1	38.1	117.7	183.7
pulsed (30 min) 1000 msec pulses	360	328	91.1	78.3	47.8	183.4	225.1	360	270	75.0	49.2	28.5	138.8	180.8
Pulsed (30 min)— 100 msec pulses	360	320	88.9	75.0	42.1	177.8	218.4	360	283	78.6	59.6	30.0	157.3	186.8
Pulsed (30 min)— 10 msec pulses	360	326	90.5	78.1	45.8	182.5	208.5	360	286	79.4	63.7	32.6	163.1	176.4

on the organism is also in direct relation to the pulse time; as this time increases, the activity of the pulse noise decreases. When the pulse time increases from 10 to 120 msec, the noise affecting the organism (with a frequency of 0.5 per second lasting 1000 msec, average intensity 80 dB) declines to 100 msec.

Research has shown that, if noise with τ = 10 msec causes significant deviations in the functional state of the central nervous system, with increased pulse time (τ) the changes become less pronounced. Pulse noise with τ = 60 msec lengthens the reaction time 32.3 msec and reduces its intensity 22.4 rel. units: noise with τ = 80 msec is reduced 23.6 msec and 18.5 rel. units, and with τ = 100 msec — to 17.8 msec and 16.1 rel. units, respectively. When the /168 pulse time is lengthened, the number of normal force ratios increases, and disturbances appear exclusively in the form of compensatory phases. Only a further increase of the time to 120 msec does not markedly weaken the activity of the sound stimulus. The shifts observed are practically equivalent, as with a pulse time of 100 msec. (Lengthening the reaction rate 18.8 msec and reducing its intensity 15.2 rel. units). The slight difference in changes is statistically not reliable ($P > 2$). In this case comparing pulse noise with stable noise showed the identical effect of this kind of noise on the organism.

To evaluate the effect of stable noise with sound pressure levels of 100 and 85 dB and maximum sound energy in the medium frequency range, B. D. Zeygel'shefer (1968) used integral methods to study the condition of animals, enabling him to detect the presence of certain undesirable shifts in the organism, independent of the point of application of the harmful factor. The author studied the effect of noise with these parameters in an experiment on animals (mice, rats) lasting 4 and 8 weeks. The ability of the central nervous system to sum subliminal pulses in experimental animals of the test groups at the beginning stages of the experiment was significantly reduced; the values of the summation-threshold index STI rose (Figure 51). These changes are evidently the result of developing inhibition in the central nervous system of the test animals. The author considers this condition as the first phase, connected with reduced excitability. As the experiment continues, STI falls sharply, which indicates an increase in the ability of the central nervous system to sum subliminal pulses. This, in turn, implies increased excitability of the central nervous system of the animals — the second phase. Phase changes of the functional state of the central nervous system are also confirmed by behavioral reactions of the test animals. In the first week of

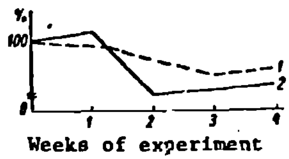


Figure 51. Changes in the summation-threshold index under the effect of noise (100 dB). 1 — control group; 2 — STI of animals subjected to noise.

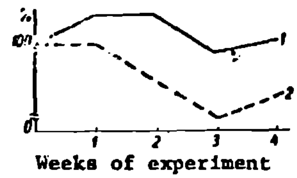


Figure 52. Changes in the weight of animals under the effect of noise with an intensity of 100 dB. 1 — control group, 2 — weight of animals during 4 weeks of noise.

the experiment, the animals congregated confusedly in the corner of the chamber. This behavior has an adaptive significance, as it partially insulates the animals from the effective noise. Another reaction is also often observed — stiffening and reduction of the motor activity of the animals, sleepiness. Later during the tests their activity increases: the animals jump around, they fight with each other, they become agressive not only during the experiment, but afterward. The relation between the expression of changes in the integral indices of the functional state of the central nervous system of the test animals and their behavioral reactions is directly dependent on the intensity level of the effective noise.

It is interesting to consider some data obtained by B. D. Zaygel'shefer /169
in studying the effect of stable noise with an intensity level of 100 and 85 dB on the organism of test animals. The author has established that the weight gain of animals subjected to the effect of stable noise of these parameters, with high reliability, lagged behind these indices in the group of control animals, both at the beginning stages of the experiment and at the end. These changes in weight evidently indicate disturbed exchange in the test group of animals. It is interesting to note that the oxygen consumption of the animals in these groups was in direct relation to changes in their weight (Figure 52), which is also verified by other researchers (V. N. Vorontsov, 1968).

The results obtained in a study of the time needed to recover the ability of linear forward movement in mice subjected to the effect of stable noise with an

intensity level of 100 dB revealed a reliable increase in this index in comparison with the group of control animals. The fact that restoration of the ability of linear forward movement was longest in animals subjected to the effect of stable noise, in the opinion of the author, can be explained by the specific effect of noise on the vestibular apparatus. The latter is verified in the works of other authors (Bugard et al., 1953; A. M. Volkov, 1958, and others). Békésy (1929, 1957) showed that when an intense increasing noise is fed through earphones, dizziness appears and the illusory movement of visible objects in space. He attributes this to the immediate effect of stimulation not only on the auditory, but also on the vestibular apparatus. In 1927, V. I. Voyachek interpreted this phenomenon as /170
irradiation — the "jumping" of stimulation from the auditory nerve to the vestibular.

It is known that the development of medical science is inseparably connected with significant achievements in one of its branches — electrophysiology. It is natural that this method also found application in the study of changes in the activity of the nervous system during the effect of a noise stimulus. However, little research has been conducted in this direction, and the data are often contradictory.

N. M. Aspisov (1948) used electroencephalography to diagnose disease in the organ of hearing in contusion victioms. In his opinion, the deafness of contusion victims is related to severe central damage to the brain stem and cortex. No response reaction to sound stimulation was observed on the EEG of those suffering deafness from contusion, while in those with normal hearing the response reaction was clearly expressed as a depression of alpha waves. The author points out that in deaf mutes with remnants of hearing the electroencephalogram accurately determined the limits and deficiencies of auditory capacity. He attributes great diagnostic value to this method in the objective study of hearing, as well as in differential diagnosis of diseases of the auditory fields of the cortex and the auditory receptor.

Interesting data have been obtained by Bugard (1955, 1958) in studies conducted on humans and animals subjected to a powerful noise stimulus. Using rabbits as the experimental object (with cortical electrodes), subjected to a 130 dB sound for 4 hours, the author showed that in response to actuation of the stimulus a reaction of desynchronization appears on the EEG, which yields to a slow rhythm with increased amplitude and the appearance of peak activity. But Bugard also points

out the lack of a direct connection between the effect and the character of changes detected in EEG tracings. In examining people who have worked in noisy conditions for several years, the author found flat electroencephalograms, nearly deprived of alpha activity; the percentage of flat recordings increased with work experience.

Dennier (1959) turned his attention to individual traits of the organism which are important in the response reaction to noise. The author indicates that the reaction to the effect of noise on the EEG of one subject was shown in the appearance of slow waves and flattening of the curve in proportion to the increased length of the effect, and in another — by increased frequency of waves and increased voltage.

I. Dimov, K. Kiryakov and I. Machev (1960) found in boilermakers, whose work is accompanied by noise with an intensity above 100 dB, low-amplitude EEG activity /171 with a predominance of delta and theta rhythms in the tracing.

The functional state of the central nervous system and the working capacity of man can be evaluated not only by the character and properties of reflexes, but also by the character and properties of bioelectric activity. This method was used in the research of A. M. Volkov, M. G. Babadzhanyan, Ye. I Kostina (1957), Ya. A. Al'tman (1960), A. M. Volkov (1961), K. Kiryakov (1964), and others.

K. Kiryakov (1964) examined 32 train dispatchers, 14 radiotelegraphers and 21 telephone operators, whose places of work were characterized by industrial noise from the equipment and speech which varied from 48 to 62 dB. The author established that people in these occupations revealed significant disturbances in the neurodynamics of cortical processes which are reflected in the bioelectric activity of the brain and at the same time appear as general functional changes in the organism. This, in the opinion of K. Kiryakov, resulted from the development of an inhibitory process in the central nervous system. The author feels that changes recorded in bioelectric activity of the brain can be used as criteria for evaluating deep functional disturbances in higher nervous activity during the effect of noise.

L. Ye. Milkov (1963a), E. A. Drogichina, L. Ye. Milkov, and D. A. Ginzburg (1965) studied the reaction to the 30 minute effect of high-frequency noise (110 dB, with frequency maxima of 1200, 1600, 4000, 6000 Hz) in groups of workers: those who had been subjected to the effect of industrial noise for a long time and

those not adapted to noise. EEG, EKG, and PG were recorded in the subjects, the critical frequency of "sound bursts", the orthostatic reflex, the Aschner-Daninini reflex and dermographism were determined. The authors found pronounced changes in all functions studied in both groups. The important role of individual sensitivity is emphasized (in some, a heightened reaction was observed and even intolerance of the sound stimulus; in other cases, unpleasant sensations were protracted). The reaction of the nervous system to noise, in the opinion of the authors, is characterized by a reduction in the functional mobility of the acoustic analysor and the appearance of synchronization (aggravation of alpha rhythm and the appearance of slow waves) on the electroencephalogram. The character of changes in the bioelectric activity of the brain, developing under the influence of noise, implies that they are connected with weakening of the activating effects of the reticular formation on the cerebral cortex.

Increased vibration frequency, decreased amplitude and the disappearance of synchronized slow rhythms from the tracing were also noted on the EKG of rats /172 (Faleg, Angeleri, 1958).

A. B. Strakhov (1964, 1965), in a series of studies on humans and animals, determined significant changes in the activity of the central nervous system during influence of high-frequency noise (90-96 dB, with maximum of sound energy in frequencies of 1500-3000 Hz). The author found that change in the bioelectric activity of the brain under the influence of noise occurs in stages: synchronized activity develops following the appearance of desynchronization. Against a background of noise, three stages in the course of conditioned-reflex activity were observed: depression, intensification in comparison with the first values and new, deeper and more prolonged depression. In people under the effect of noise the author found a pronounced depression of alpha rhythm as the test progressed. Preservation of these changes was also in direct relation to the length of the experiment. The author feels that the effects he observed are connected with a change in the functional state of the reticular formation of the brain stem, which progresses in proportion to the noise effect.

Analogous changes were detected by A. M. Volkov (1958, 1961, 1963) in studying bioelectric activity in locomotive engineers. He showed that noise with an intensity of 75 dB causes depression of alpha rhythm in passenger car personnel, and the more intense noise of locomotives (over 90 dB) leads to still greater depression

of alpha rhythm. The author points out that physiological shifts are increased with the combined effect of noise and vibration.

Apostolov (1968a, b) analyzed the electroencephalographic reaction of awakening in the cortex of the large hemispheres of a rabbit which develops in response to the repeated presentation of an unreinforced sound stimulus (200-400Hz). In proportion to the length of the experiment, desynchronized activity was replaced by synchronized fluctuations with a frequency of 5-7 Hz in the front sensory-motor area; in the posterior part of the parietal area of the brain synchronized rhythms remained less pronounced. The author feels that the phenomenon of an altered form of response to a repeatedly-experienced unreinforced stimulus must be taken into consideration in analyzing shifts in the electroencephalogram which are observed during the course of studying conditioned-reflex activity.

Extremely interesting is the research of Saito (1964a,b) studying the effect of white and octave bands of noise (75-150, 300 - 600, 1200-2400, 4800-9600 Hz from a sound generator with three stages of intensity — 90, 70 and 50 dB) on healthy males aged 20-30 years. The experiment was conducted in a chamber with minute exposure to noise. EEG from only the left occipital area, galvanic-skin reaction /173 and respiration were recorded. The dependence of parameters of the effective noise stimulus on specific components of the background EEG were shown.

Similar results were obtained by Sujuki, Toratani et al., (1958); they studied the effect of pure tones of 500, 1000, 4000 and 6000 Hz and noise on the bioelectric activity of the brain. They showed that, when the intensity of noise is increased, an increasing number of changes is observed on the electroencephalogram.

I. Ya. Borshchevskiy and E. V. Lapayev (1965) conducted studies on 15 subjects placed in a soundproof chamber, supplied with jet engine noise recorded on magnetic tape. They studied the effect of aviation noise with an intensity of 100-102, 110-112, 118-120 dB, lasting 1.3 and 6 hours. They determined the activity of the cardio-vascular system, the condition of acoustic and visual analysors, changes in the central nervous system by proofreading tables and arithmetic tests, the functional state of higher autonomic centers by plethysmography; EEG was recorded in the frontal parietal area. It was established that the one-time effect of airplane noise with an intensity of 110-112 dB for 1 and 3 hours and noise with an intensity of 100-102 dB for 6 hours does not cause marked changes in the acoustic

analysor or in other functional systems of the organism. After the effect of 110-112 dB and 120 dB noise for 6 hours, in the majority of cases an increase in integral values of low frequency vibrations was noted on the EEG. The authors feel that such changes in the bioelectric activity indicate that the cerebral cortex is changing to a new level of functioning because of the development of an inhibitory process.

Fusko, D'Amoto, Collucci, and Fimiani (1965) studied the effect of noises and sounds on the bioelectric activity of the human brain. They simultaneously recorded a cerebral and peripheral rheogram. The study was conducted on 20 subjects, of which 10 were subjected to the effect of a pure tone of 400 Hz and intensity of 100 dB for 15 seconds. The EEG of these persons showed a pronounced reaction of interrupted alpha rhythm, which disappeared before the end of the sound effect. Desynchronization was noted on the EEG of the other 10 subjects who were subjected to the effect of "industrial" noise with an intensity of 100 dB for 30 minutes. The combination of changes observed in the bioelectric activity of the brain and the central and peripheral rheogram led the authors to conclude that noises have a direct effect on the vasomotor centers of the brain. /174

Several works deal with the effect of a sound stimulus on the bioelectric activity of various sections of the central nervous system of animals.

O. V. Berzilova, V. F. Mostun and G. N. Erdman (1962) studied the effect of rhythmical sound stimuli on the biopotentials of the auditory section of the cortex and subcortical structures of dogs. After repeated application of a sound effect, theta waves developed in the reticular structures of the brain which began to appear in the structures of the auditory tract as well as in the area of the cortical section of the acoustic analysor in proportion to the length of the test.

Experimental research has shown that auditory stimulation can lead to motor responses of the spinal cord. Stimulation of the auditory apparatus of the right ear (the left inner ear was destroyed) with equivalent sound clicks on intact cats, narcotized with chloralose and decerebrized, caused the appearance of reflex electric discharges in the anterior roots of cervical, thoracic, lumbar and sacral segments. On the basis of this study, the authors conclude that auditory stimulations of projection pathways of the auditory receptor alone are able to activate under certain circumstances, the system of net-like neurons, which is the source of

descending pulses. They in turn stimulate motoneurons of motor nuclei in various segments of both sides of the spinal cord. Cutting the spinal cord in half at level C did not, with respect to the sound stimulus, cause any changes in the character of reflex electric discharges from the anterior roots of lumbar segments.

The authors suggest that descending pathways of the acoustic spinal reflex are a partially diffuse projection system of the spinal cord and participate in the response reaction of the central nervous system to sound stimulation.

There is a large number of works (S. N. Gol'burt, 1964; N. N. Vasilevskiy, 1968, and others) which present electrophysiological studies with macro- and micro-electrodes of various sections of the auditory tract using various acoustic stimuli. This is also dealt with in the works of G. V. Gershuni (1962, 1964) on electric responses of the auditory tract, and Ye. A. Rodionova (1965) on a study of responses of isolated neuronsof the auditory tract.

A great deal of factual material has now been accumulated (Ya. A. Al'tman and A. M. Maruseva, 1949; G. V. Gershuni, 1965; G. V. Zaboyeva, 1962, and others) which indicates that total electric responses of various sections of the auditory system reflect the starting moment of the effect of sound stimulation. /175

G. B. Gershuni (1965) also posed the question of using the reactions to sound on the EEG to study hearing (so-called objective audiometry). EEG reactions to sound are used to determine thresholds of the sound frequency curve (audiometry by EEG changes) in man. V. A. Kozhevnikov and A. M. Maruseva (1949) determined subliminal subsensory reactions to sound.

There are isolated studies dealing with changes in the bioelectric activity of deep sections and the cortex of the human brain during sound stimulations (N. P. Bekhtereva, K. V. Grachev, R. Gombi, 1963; R. Gombi, 1964; Walter, 1969, 1966; V. Ye. Mayorchik, 1964; N. P. Bekhtereva, 1965, 1966, 1967, and others).

R. Gombi (1964), studying the parameters, dynamics and nature of electric effects of sound stimulations in various deep brain structures of people suffering from hyperkinesis and epilepsy, recorded induced nonspecific reactions of the secondary response type, desynchronization and synchronization of biopotentials, the reproduction and retention of a stimulating rhythm in response to single and

rhythmic sound stimulations. The parameters of electric effects depend on the functional state of the subject, background bioelectric activity, and the parameters of the applied sound stimulus.

Summarizing this data, it can be concluded that pathological shifts developing under the influence of noise depend on its intensity, length of effect, initial functional state of the central nervous system, individual sensitivity, and attendant industrial and every-day factors.

We must point out the high sensitivity of the central nervous system to noise. Changes in the functional state of the central nervous system, according to the data of the majority of authors, appear earlier and even at noise levels which do not yet disturb the sharpness of auditory sensitivity.

Electrophysiological Shifts in Various Sections of the Brain

A study of the reactions of the central nervous system to noise begins with establishing the character of the background bioelectric activity of individual nerve structures of the brain of animals. To avoid changes in bioelectric activity caused by the effect of experimental conditions, the recording was begun 30-60 minutes after placing the animal in the chamber. /176

The background bioelectric activity of the brain of rabbits has been studied by a number of authors (M. N. Livanov, 1960; V. I. Gusel'nikov, A. Ya. Supin, 1968, and others).

A distinctive feature of the background electric activity of the brain of a rabbit is its polyrhythmic character, which essentially distinguishes it from the EEG of cats, monkeys and man, which are characterized by a predominant rhythm in a state of rest. A study of the EEG of various sections of the brain verifies that they can reveal traits characteristic of individual areas of the brain.

The amplitude of biopotentials of the brain in the tests of A. V. Kadyskin varied between 80-90 μV. EEG of the cervical area has a pronounced polyrhythmical character, i.e., it is composed of fluctuations of varying frequency. These fluctuations cover a frequency range from 2 to 45 Hz. Fluctuations of 30-40 Hz have

little intensity and are encountered rarely, but those lying between 12-15 Hz, related to spindles, are more pronounced. The next range includes fluctuations with a frequency of 5-8 Hz, which are related to the so-called "basic" rhythm of a rabbit. And, finally, potentials with a frequency of 2-3 Hz are also encountered here; these usually have considerable amplitude, and to a large degree affect the general intensity of electric fluctuations.

The biopotential tracing of the sensory-motor area has a number of characteristics to compare with the electrogram of the cervical zone. Firstly, the EEG of the sensory-motor area often lacks basic rhythm fluctuations, and if they are encountered, they are very weak. Secondly, slow fluctuations (5-6 Hz) are very pronounced here. Thirdly, spindles are seen in the electrogram of the sensory-motor zone more often and are much more pronounced: and, finally, fourthly, a significant number of high-frequency fluctuations (over 50 Hz) are sometimes noted in the biopotentials of the sensory-motor area, revealing a tendency toward grouping in the form of spindles.

In studying the bioelectric activity of the auditory zone of the cortex, it was shown that basic rhythm fluctuations which are well distinguished are most often encountered in this zone. With regard to other fluctuations, potentials with a frequency of 10-15 Hz are more pronounced, alternating with infrequent (5-8 Hz) or more frequent ones (20-25 Hz); the amplitude of fluctuations, as a rule, is not great.

The background rhythm of the cortex is a very dynamic picture. The bioelectric pattern of the cerebral cortex during long observations of rabbits in a state of rest is repeated periodically. Different variations appear in each repetition which are connected with an increase or decrease of amplitude or frequency, with slight change in the potentials of a certain zone, but basically the course and character of the activity remain constant for a comparatively long time. But, remaining stable for several seconds or minutes, the pattern of bioelectric activity suddenly or gradually "switches" again. Often unusual switchings of activity can be observed from the cervical to the frontal areas of the hemisphere and back. This becomes apparent in that the more or less pronounced increased activity of anterior areas of the brain leads to the simultaneous development of depression of activity, i.e., reduced amplitude of potentials without change of frequency in the cervical zones. Thus, reciprocal ratios appear in the background bio-electrical activity of the cerebral cortex of rabbits between sections of the /177

hemispheres, which reveals a close interrelation in their activity. I. P. Pavlov (1951) has written: "If, from one point of view, the cortex of the large hemispheres can be considered as a mosaic of an innumerable mass of individual points with a certain physiological role at a given moment, then, from another point of view we see in it a complex dynamic system, constantly striving for unification (integration) trying to stereotype unified activity."

Studying the important role of the cortex of the large hemispheres in the process of higher nervous activity, I. P. Pavlov also constantly emphasized the interconnection and interaction of the cortex and subcortical sections of the nervous system. I. P. Pavlov (1951) noted that subcortical centers to a greater or lesser degree determine the active state of the large hemispheres and thus variously change the relationship of the organism to the medium.

The use of long-term intracerebral electrodes was an extremely valuable means of obtaining the most accurate and complete information about the character of bioelectric phenomena of various subcortical structures. We must note that the character of background electric activity in frequency, and especially in amplitude was not the same in the electrogram (EG) of various sections of the reticular formation. Thus, waves with a frequency of 5-7 per second are most typical of the electrogram of the reticular formation of the pons varolii, while the electrical activity of the reticular formation of the mesencephalon fundamentally resembles the EG of the optic area. However, the basic rhythm fluctuations are more pronounced here than in the optic area, and the fluctuations of other frequency ranges, on the contrary, are less pronounced.

Concerning the basic background of electrical activity of nonspecific nuclei of the thalamus, their characteristics are dominated by basic rhythm fluctuations with a somewhat lower amplitude on which faster oscillations with a frequency /178
of 8-15 per second are usually superimposed.

The bioelectric activity of the lateral nuclei of the thalamus is seen in the form of fluctuations of small amplitude with a frequency of 6-8 per second, often alternating with more frequent fluctuations.

Studying the minimum fluctuations of electric currents of the brain at rest enables the researchers to determine waves which are potentials of brain tissue and fluctuations which develop in the brain as a result of the effect of internal

stimuli on the afferent systems. For the first, the name "spontaneous fluctuations" has been adopted and for the second, developing as a result of stimulations of afferent systems — "induced potentials." However, it must be pointed out that these names are arbitrary, as spontaneous electric activity is the result of the constant effect of minimum stimuli of the external and internal environment which create conditions for a state of wakefulness of the entire organism.

There are a number of studies which convincingly show that a sound stimulus in a number of cases can change from indifferent to pathogenic, leading to pathophysiological, clinical, and morphological disturbances. It might be expected that this complex of disorders, developing during noise, is reflected in the bioelectric pattern, which is a reflection of the functional state of the central nervous system. For greater objectivity in evaluating the effect of noise on bioelectric activity of brain structures, A. V. Kadyskin conducted a study and statistical analysis of parameters of the electrical activity of the brain of rabbits. In his research, the author dynamically studied the changes which appear in the bioelectric activity of various structures of the cortical and subcortical level of the brain, as well as "behavioral" and several autonomic reactions of the animals for 36 days under the influence of wide-band stable noise with an intensity level of 120 and 90 dB. We must note that the reaction to actuation was different in both groups of animals; this, of course, the author attributes to differences in the force characteristics of the noise (group I — noise of 120 dB; II — 90 dB).

The noise was actuated simultaneously with recording the bioelectric activity of the brain. The animals in the first group (activation of 120 dB noise) shuddered, they showed sharp motor agitation (running, jumping, etc). Then the rabbits began to "shake themselves," there appeared tic-like twitchings of the head, tremor, especially often encompassing the muscles of the extremities. Involuntary defecation and urination appeared in some animals. In proportion to the effect of the noise, the motor /179
activity of the animals significantly decreased. They huddled in the corner of the cage, pressing themselves tightly against the bottom, assuming a passive pose. The rabbits "sort of faded away," after which a new stage of motor agitation began. Subsequently more and more marked muscular weakening of the animals developed. They became very quiet, rarely changed their position, even rarely turning their head.

We must note that in the second series of experiments, actuating a 90 dB noise, an orientating-investigating reflex appeared in the animals (sniffing, looking around

etc.), preening movements, "washing," licking their hair. No pronounced motor disturbances were noted. But in the majority of the rabbits in the first days of the tests a slightly expressed twitching of the chewing muscles could be ascertained, "shaking." With rabbits in this group, such pronounced depression as with those of the first group was not noted. When the noise was deactivated, the animals also remained in a quiet state; however, when they were touched they expressed fright, flinching and in the first days of the experiment even agressiveness. The limpness of the first group was not found. The rabbits were more active, they accepted food right away. But by the 20-23rd day disappearance of fright could also be noted in them, limpness increased, drowsiness appeared more often, and when the noise was turned off the animals assumed a passive-defensive pose for a short time and then again became listless and sleepy.

These behavioral reactions of the animals were observed by A. V. Kadyskin in the majority of animals with respect to the first and second series of experiments. However, it must be pointed out that in both the first and in the second groups, there were animals whose reactions did not agree with those described above. Thus, in the first group, activating the noise caused a persistant passive-defensive reaction in two of the rabbits which dominated the behavior of the animal for a long time, and one rabbit evidenced complete "intolerance" to noise, which caused so much agitated movement that it was impossible to record the electrogram and he was eliminated from further studies. In the second group, every time the noise was activated one animal had a "desire" to come closer to the loud-speaker producing the noise. The behavior of the animals also indicated different reactions in both groups to the applied noise stimuli, which increased in prpportion to the length of the noise.

On the basis of the results of the experiment, A. V. Kadyskin distinguished two phases in the "behavior" of the rabbits: first — an active phase (for the first /180 group — 7-10 days, for the second — 15-18 days) and second — a continually progressing, passive phase.

The "behavioral" reactions of the animals correspond to changes expressed in the electric activity of the cortex and subcortical structures of the brain, which probably indicated deep functional changes in the central nervous system.

When the noise was activated, an extremely typical reaction of the bioelectric

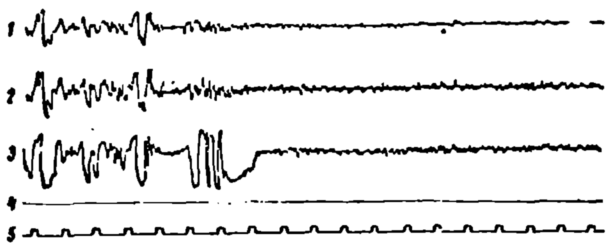


Figure 53. Bioelectric activity of brain structures with the activation of a wide-band stable noise with intensity of 120 dB. Cortex: 1 — auditory zone. 2 — cervical zone; subcortex: 3 — reticular formation of mesencephalon. 4 — stimulation mark — activation of noise; 5 — time mark.

activity of the brain was observed in both groups of experimental animals (Figure 53). First of all, there was a very pronounced reaction of desynchronization — synchronized wave activity was replaced by less regular fluctuations of various length. A similar electric activity was more clearly expressed in the cortical leads. In the reticular formation of the mesencephalon, pons and thalamus, a significant reduction in the amplitude of bioelectric potentials was recorded. After brief desynchronization, synchronized fluctuations of the basic rhythm with a frequency of 6-7 per second began to predominate in these structures, alternating with low amplitude fluctuations. The generalized changes produced in the background electric activity of the cortex and subcortical structures upon activation of an afferent stimulus, the noise, were set into a pattern designed in electrophysiological literature as the arousal reaction. These changes indicate the nonspecific character of the response reaction of brain structures studied to the effect of a noise stimulus.

At the present time, there is a considerable amount of accumulated material about the undoubted connection between generalized changes in the background rhythm /181 and excitation of the reticular formation. This is indicated primarily by the porphophysiological properties of the reticular formation of the stem which receives collaterals from all sensory afferent pathways and is diffusely connected with all sections of the cortex (Megun, 1965, and others).

On the basis of a large amount of research, it can be stated that the accustic analysor along its entire length from the peripheral end to the cortical has a

large number of complexly structured intermediate centers, as well as connections with other nonspecific structures of the brain (Galambos, 1959; Tsimerman, 1967, and others).

Thus, generalized changes in the electrical activity of the brain, recorded by A. V. Kadyskin in both groups of animals during the effect of noise can evidently be explained by the enriched collaterals between specific afferent pathways and the reticular formation which is very important in the development of generalized changes in the bioelectric pattern of the brain (P. K. Anokhin, 1962; Megun, 1965; Yu. S. Borodkin, 1967).

We must note that the described electric activity of the cortex and subcortical structures predominates in the electrophysiological pattern of the first days of the experiment. In the cortical zone of the acoustic analysor, a clearly expressed reaction of desynchronization is strictly maintained; in the cervical area slow fluctuations often appear on which "spindles" with a frequency of 10-12 per second are superimposed. In these periods, bursts of frequent low-amplitude activity develop in the sensory-motor area. Bioelectric activity of the cerebral cortex also presents an extremely polymorphous dynamic pattern, in which low-amplitude frequent fluctuations predominate. Slow theta-waves (5-7 fluctuations per second) also appear periodically in the sensory-motor area which are accompanied by pronounced desynchronization in the auditory zones of the cerebral cortex. However, at times these electric fluctuations suddenly gave way to general desynchronization of all brain areas studied, lasting from fractions of a second to several minutes. General desynchronization, encompassing the structures of the cerebral cortex, developed periodically during the noise effect, but by the end of the noise exposure its length was significantly shortened, lasting fractions of a second.

Changes in the functional state of the cerebral cortex, in the genesis of which the reticular formation plays an important role, in turn are able to decrease as well as increase the excitability of deep brain structures by means of existing cortico-reticular effects. The author also observed an extremely varied electrographic pattern when the next noise effect was actuated. Pronounced depression of the back- /182 ground rhythm develops in subcortical structures. A predominance of low-amplitude frequent fluctuations (reaction of desynchronization) is observed in the medial, ventral and lateral reticular nuclei of the thalamus, the reticular formation of the mesencephalon and the pons. Thus, generalized changes can be ascertained which indicate the general reaction of these brain structures to the effect of a noise

stimulus. However, it must be pointed out that the severity and length of this reaction in various brain structures was different. Desynchronization disappeared successively first in the reticular formation of the mesencephalon and then in nonspecific nuclei of the thalamus. On the other hand, low-amplitude activity was maintained longer in the lateral nucleus of the thalamus and the reticular formation of the pons, alternating with the development of basic rhythm fluctuations. Then relatively long intervals of desynchronization in the cortex, especially in the auditory and sensory-motor areas (from 2 to 10-15 seconds, and sometimes up to several minutes), were combined with brief recordings of faint depression of basic rhythm in the subcortical structures, which alternated with polyrhythmic electric activity with a significant reduction of potential amplitude in comparison with the background recording.

The predominance of basic rhythm fluctuations in proportion to the effect of the noise in longer studies of electrograms of subcortical structures is noteworthy. This was especially pronounced in the reticular nuclei of the thalamus and the reticular formation of the mesencephalon. More frequent fluctuations were also recorded in the subcortical zones, but they were relatively weak.

A comparison of changes in the bioelectric activity of various levels of the brain in both series of experimental animals showed that basically they have the same direction, but a varying degree of expression. The electrical reactions of brain structures under the effect of noise with an intensity of 90 dB were shorter, more polymorphous and often alternated with EEG intervals which were very close to background recordings.

The change in force characteristics of noise was one of the important methodological means used to evaluate the functional state of the central nervous system. Tests on the first days showed that more intense noise has a deeper effect on the bioelectric activity of these brain structures. The ratio between the force of the stimulus and the length of the reaction indicates the important role of functional properties of the brain structures in the response reaction to noise. /183

Observations of the dynamics of the cortex and subcortex enabled A. V. Kadyskin to find one more type of electrical activity in the first days which indicates, evidently, the development of pathological excitation. We are talking about the development and irradiation of high-voltage acute wave fluctuations from the auditory

area of the cerebral cortex of test animals. These fluctuations appeared most often after depression of activity and were accompanied by motor effects (tremor of chewing muscles, "shaking," etc.). Analogous activity appeared at this time in the sensory-motor zone against a background of pronounced desynchronization; in the cervical zone of the cortex, basic rhythm predominated. However, relatively low-amplitude slow waves continued to be maintained in subcortical structures; sharp fluctuations and sometimes even peaks began to appear among them periodically. This electrophysiological pattern was found primarily in the reticular and medial nuclei of the thalamus, the reticular formation of the mesencephalon and the . Sometimes high-voltage sharp-wave activity was recorded against a background of very pronounced desynchronization in the auditory area of the cerebral cortex and the lateral nucleus of the optic lobe. Pointed fluctuations of basic rhythm were observed in the reticular formation of the mesencephalon, alternating with sharp small-amplitude waves. Then sharp waves with an amplitude of 80-140 μV began to be recorded in all nerve formations under study. It is typical that the author detected significant depression of bioelectric activity following a relatively small burst of sharp-wave activity in those zones where it was more pronounced. It is evident on the EEG that pronounced depression of potentials appears in the auditory zone after high-voltage (over 200 μV) sharp waves with succeeding new "volleys" of peak discharges. In the ventral nucleus of the thalamus and the reticular formation of the mesencephalon, pointed low-amplitude fluctuations predominate, analogous to those which are recorded in the cervical area. It must be pointed out that these electrical shifts were primarily observed in the first 30 minutes of the noise effect, correspondingly decreasing by the 8-10th exposure, and the intensity of reactive effects progressively dropped, both by the end of the experiment and from test to test.

Thus, electrophysiological characteristics of subcortical formations are characterized by extremely large variability of both types of electrical activity of brain structures and parameters of potentials, which was less pronounced with 90 dB noise. /184

Electrographic changes, caused by a noise stimulus, are accompanied by parallel changes of electrical activity in the cortex as well as in the subcortex, and, therefore, evidently also by a synchronized shift of nerve processes, i.e., cortical and subcortical levels participate in the response reaction of noise in step. Definite changes were determined by the author in the frequency and amplitude of potentials.

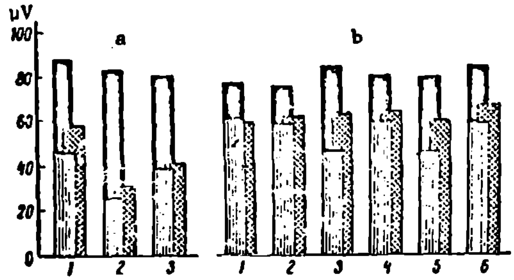


Figure 54. Change in the mean amplitude of biopotentials of the brain in both groups of animals on the second day of the experiment. a. — cortex; 1 — cervical zone; 2 — auditory zone; 3 — sensory-motor zone; b — subcortex; 1 — reticular formation of the pons; 3 — reticular nucleus of the thalamus; 4 — medial nucleus of the thalmus; 5 — lateral nucleus of the thalamus; 6 — ventral nucleus of the thalamus. Black columns — control; columns with straight shading — noise of 120 dB; columns with crosshatching — noise of 90 dB. Vertically — amplitude.

Simultaneous recording of the bioelectric potentials in various levels of the brain during the direct effect of a noise stimulus enabled A. V. Kadyskin to find nerve formations with the most severe electrophysiological shifts, as it is known that structures in which the most intense bioelectric changes occur are in a state of the greatest activity.

Analysis of electroencephalograms recorded during application of the noise stimuli led to the detection primarily of differences in the electrical activity of cortical and subcortical structures. Results of statistical analysis of experimental data from the second day of the noise effect are given in a graph for the first and second groups of rabbits respectively (Figure 54). /185

From these data, it is evident that in both the first and in the second group, by the second day the amplitude of potentials drops considerably. Under the effect of noise with an intensity of 120 dB, a more pronounced decrease occurs in comparison with the control group than with 90 dB noise. This depression of electric activity occurs primarily in the second phase of each experiment (passive) and is recovered rather slowly — in the first group in 30-45 minutes, and in the second in 5-15 minutes after the noise stops.

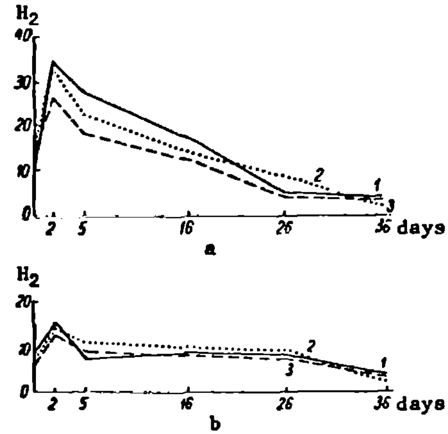


Figure 55. Dynamics of mean frequency of fluctuations of biopotentials of the cortex and subcortical structures of the brain for the test period (noise o 120 dB).
a — cortex; 1 — optical, 2 — auditory, 3 — sensory-motor zones; b — subcortical structures of the brain: 1 — reticular formation of the mesencephalon; 2 — reticular formation of the pons; 3 — lateral nucleus of the thalamus. Vertically — frequency.

Figure 55 shows the results of frequency analysis of electrograms for the test period. As can be seen, the frequency of fluctuations with 120 dB noise increases in the first days of the experiment, especially clearly in the auditory, sensory-motor and cervical areas of the cortex and is especially predominant in comparison with subcortical structures. Frequency-amplitude characterisitcs of the brain structures during the noise in this period are given in Tables 33 and 34 (P given in relation to the control). In most of the columns it is less than 0.01, /186 with the exception of: in Table 33 — on the 2nd day in the 7th column $P < 0.05$, in the 8th — 0.1; in Table 34 — on the 5th day in the 8th column $P < 0.02$; in the 10th < 0.05; on the 16th day in the 6th column $P < 0.05$, in the 9th < 0.2, and in the 10th < 0.1.

An analogous pattern, but less pronounced, can be observed in exposure to noise with an intensity of 90 dB.

As can be seen from these tables, the amplitude of fluctuations is simultaneously reduced in the cortex and in subcortical nerve formations in the animals of both experimental groups. In the cerebral cortex, the intensity of potentials decreases more than three times in comparison with data obtained in background tracings. This reduction is statistically reliable. However, a significant reduction of amplitude

TABLE 33

MEAN (M ± m) AMPLITUDE OF BIOPOTENTIALS IN CONTROL AND TEST ANIMALS DURING 120 dB NOISE (IN μV)*

Time of study, days	Auditory zone of cerebral cortex	Optic zone of cerebral cortex	Sensory-motor zone of cerebral cortex	Reticular formation of mesencephalon	Reticular formation of pons	Reticular nucleus of thalamus	Medial nucleus of thalamus	Lateral nucleus of thalamus	Ventral nucleus of thalamus
1	2	3	4	5	6	7	8	9	10
Control	83,4±1,74	88,6±1,87	80,8±1,00	77,8±0,60	74,7±0,86	84,2±0,34	80,0±0,68	79,3±0,90	83,3±1,20
2	25,6±1,35	46,7±1,47	39,1±0,87	62,1±0,92	58,2±0,59	46,7±0,96	59,2±0,58	45,8±1,28	58,2±0,62
5	42,6±1,01	100,1±2,50	98,5±1,25	90,7±1,90	87,6±0,32	80,0±1,30	82,1±1,38	89,2±0,85	90,3±1,90
16	48,3±1,20	60,9±1,32	53,3±1,35	63,6±0,90	55,8±1,10	60,6±1,00	58,1±0,73	49,6±0,49	61,4±0,79
26	38,0±1,40	58,1±1,23	49,2±1,20	62,3±0,68	46,1±1,28	58,1±0,68	52,6±0,62	49,8±0,49	52,8±1,10
36	40,8±0,91	42,8±1,79	40,2±0,64	36,2±0,90	39,1±0,75	46,6±0,49	40,3±0,49	47,4±0,41	44,3±0,53

*Commas represent decimal points.

TABLE 34

MEAN (M ± m) FREQUENCY OF CEREBRAL BIOPOTENTIALS OF CONTROL AND TEST ANIMALS DURING 120 dB NOISE IN Hz*

Time of study, days	Auditory zone of cerebral cortex	Optic zone of cerebral cortex	Sensory-motor zone of cerebral cortex	Reticular formation of mesencephalon	Reticular formation of pons	Reticular nucleus of thalamus	Medial nucleus of thalamus	Lateral nucleus of thalamus	Ventral nucleus of thalamus
1	2	3	4	5	6	7	8	9	10
Control	12,8±0,66	14,8±0,66	15,3±0,60	9,7±0,50	7,8±0,40	8,9±0,29	8,7±0,23	9,6±0,53	9,1±0,36
2	34,1±1,53	27,4±1,04	32,8±0,34	14,2±0,25	13,3±0,45	14,3±0,47	12,6±0,45	13,8±1,04	14,1±0,68
5	27,2±0,91	18,6±0,62	22,4±0,55	7,1±0,40	8,2±0,19	7,1±0,34	9,6±0,25	10,3±0,36	10,5±0,19
16	15,8±0,30	9,7±0,27	12,3±0,62	6,4±0,10	5,9±0,25	6,[illegible]±0,32	10,3±0,45	7,1±0,28	7,9±0,40
26	6,4±0,19	6,1±0,25	9,6±0,15	4,8±0,15	4,4±0,19	5,1±0,23	4,8±0,19	5,[illegible]±0,32	4,9±0,12
36	2,9±0,15	2,7±0,12	2,7±0,30	2,4±0,08	2,4±0,06	2,6±0,10	2,8±0,08	2,[illegible]±0,06	[illegible],6±0,08

*Commas represent decimal points.

/187

is also noted in subcortical sectionsof the brain. Thus, we see that the intensity of potentials of nuclei of the optic lobe and reticular formation decreases almost 2-2.5 times in comparison with the initial data. The amplitude of the electrograms of subcortical sections of the brain in these rabbits also statistically reliably differs from the amplitude of the cerebral cortex in these same animals.

The results show that significant and statistically reliable reduction of the biopotential amplitude also takes place in animals in the second group by the fifth day of the noise effect. On the average, the EEG amplitude of the auditory zone is reduced in rabbits almost 1-1.5 times in comparison with the control. Unlike the animals in the first test group, their biopotential amplitude decreased evenly in all sections, as here there is no sharp drop in amplitude of the electrograms /188
as described above for subcortical sections of the brain.

The effect of noise during the first five days caused pronounced qualitative and quantitative reorganization of the electric activity of the brain, which reflects shifts in its functional st and indicates the brain's conversion from a "quiet" state to "active" in the first phase of the experiment. The reduction of amplitude and frequency of bioelectric potentials of various levels of the brain, especially by the end of the experiment, indicated the transfer of the brain to another level of dynamic condition — inhibition. Electrophysiologically this was shown by synchronized slow-wave activity in all nerve formations studied. It is important to note that even during the first exposures to 120 dB noise, slow low-voltage fluctuations with a frequency of 2-4 per second appeared in the rabbits in the reticular formation of the mesencephalon and in the lateral nucleus of the thalamus. The amplitude of these potentials was low and varied between 50-60 μV.

Such electric activity can also be observed in the auditory zone where it appeared episodically following low-amplitude frequent activity. At the same time, frequent fluctuations of low amplitude were recorded in the nonspecific nuclei of the thalamus. Thus, the fact can be ascertained that developing delta and theta waves gradually encompass one brain structure after another, proceeding from the subcortex to areas of the cerebral cortex. This phenomenon began to predominate by the end of three hour's exposure to noise and was more pronounced by the 7-9th days of the experiment. Slow low-voltage activity with a frequency of 2-4 Hz encompassed the sensory-motor area of the cortex, proceeded to the cervical zone, then was also established in the auditory zone. This was accompanied by low-amplitude frequency

activity of the nonspecific nuclei of the optic lobe, and synchronized low amplitude fluctuations with a frequency of 3-4 Hz appeared in the reticular formation of the mesencephalon and the pons. By the 10-12 day, the character of electric activity of brain structures acquired a certain uniformity, which can be clearly observed in a frequency-amplitude analysis of bioelectric potentials of various brain structures of the animals. The background activity of the brain is also definitely depressed, and if a pronounced nonuniformity of reactions of brain structures is noted by the fifth day of the experiment, on the tenth day an even synchronized depression of bioelectric potentials can be observed in these subcortical formations of the central nervous system of the animal. /189

With respect to the electrophysiological reactions of the brain to the effect of noise with an intensity of 90 dB, by the 10th day uniform slight depression of the background rhythm appeared. In the electrosubcorticogram of the animals in this group, a predominance of the basic rhythm was observed, which was significantly reinforced by this time.

Characteristic changes in bioelectric activity were evident in the aftereffects period. We must point out that deactivation of the noise often caused dissimilar reactions. If it happened against a background of slow-wave activity, a generalized reaction of desynchronization appeared. However, if low-amplitude frequency activity was present, deactivation increased the biopotential amplitude. The length of these reactions decreased from test to test, and by the end of the experiment, the time of the reaction to deactivation was quite short, an average of 2 ± 0.25 seconds.

Recording electric activity in the after period showed that during the influence of noise with an intensity of 120 dB, the EEG did not return to normal, even after the first three hours.

After 4-6 experiments it was discovered that an hour after the noise, the same fluctuations were observed on the EEG which were recorded during the noise, but with greater amplitude; the "background" EEG, after the eighth day of the noise, differs significantly from the spontaneous activity of the same rabbit on the first day of the experiment.

Subsequently, there was a gradual accretion of changes in the electrographic tracing obtained before each experiment. This indicated that the shifts detected in bioelectric activity were permanent and were accumulated and summarized in

proportion to the course of the experiment. Bioelectric changes were detected not only in the cortex, but in the subcortex as well, which shows the close interaction and participation of the cortex and subcortex in the response reaction to noise.

Subsequent study of the electrophysiological changes in the cortex and subcortex enabled A. V. Kadyskin to find an ever increasing tendency for slow-wave low-amplitude activity to develop. This is seen in the fact that in subcortical structures (in the reticular formation of the mesencephalon, pons, and in the medial nucleus of the optic lobe) a four fluctuations-per-second rhythm is developed and reinforced, which appears in these areas of the brain even in the first tests. A reaction of desynchronization was determined in the auditory zones; in the sensory-motor and cervical zones, basic activity began to predominate, but with low amplitude. However, in proportion to the effect of the noise, slow fluctuations began ever-increasingly to "penetrate" the auditory zone. It could be observed that after the 14-16th day, slow waves with a frequency of 3-4 per second appeared on the EEG of auditory areas /190
of rabbits after only 15 minutes of the noise. These were synchronized with vibrations determined in the reticular formation of the mesencephalon, medial, and ventral nuclei of the thalamus. A pronounced curtailment of fluctuations with depressed amplitude was also observed in other subcortical structures.

In electrograms of the brain of rabbits, recorded during this period, it was still possible to note several elements of polymorphism of electric activity in subcortical structures and, especially, in the cortex. Simultaneous recording of EEG and respiration showed that rhythms with a frequency of 3-4 Hz, predominating in the electrogram of the brain, correspond in frequency, and often in amplitude as well, to respiratory movements. It was discovered that after prolonged noise of great intensity, fluctuations in this range also begin to appear in the lateral and reticular nuclei of the thalamus as well as in the cortical part of the acoustic analysor, replacing the reaction of desynchronization. At that time, the rapid activity of other cortical zones significantly decreases.

It is interesting to note the fact that, if in the first half of the experiment (12-14 days), the progressing effect of orderly synchronized rhythm with a frequency of 3-5 fluctuations per second primarily occurred in the reticular formation of the stem and thalamus, the second half (16-26th day) was characterized by the development, generalization and reinforcement of this rhythm. Prolonged and regular

application of a strong noise stimulus caused the process of synchronizing the rhythm of electric fluctuations to be very pronounced in all the specific and nonspecific nerve formations we studied, and, as we have indicated, it coincided with the rhythm of respiration. In fact, even by the 18-21st day, synchronized rhythm became the dominant form of electric activity in the cortex (sensory-motor, auditory, cervical) and subcortical structures (lateral, medial, ventral and reticular nuclei of the thalamus and reticular formation of the mesencephalon and the pons). Amplitude analysis shows that brain structures at this time evidently transfer to an identical level of functional activity. The biopotential amplitude of the brain of the rabbit on the 21st day of the noise varied only very slightly.

Further observations of the dynamics of bioelectric activity of the cortex and subcortical structures do not reveal essential shifts in its character. Against a background of this uniform EEG, synchronized "bursts" of 3-5 delta waves appeared in all sections with a frequency of 2 fluctuations per minute, whose /191
amplitude was about 2 times greater than the basic activity. It is interesting that these fluctuations began to spread very quickly to all brain structures, and by the end of the experiment, by the 24-26th day, generalized low-amplitude synchronized slow-wave activity appeared in all the brain structures under study (Figure 56). This bioelectric activity was also maintained in the after period and even to the next day of testing. Actuating the noise against such a background caused only slight intensification and increased frequency of electric activity of the brain, which then rapidly assumed its "original" character.

On the 36th day of the experiment, electric activity of the brain was represented almost entirely by delta waves, the amplitude of which varied slightly, averaging 40 μV .

The dynamics of changes in brain biopotentials during noise with an intensity of 90 dB was analogous to that described. But a noise stimulus with a 90 dB intensity did not cause such pronounced depression of potential amplitude; it caused a slightly increased rate of fluctuations. However, recovery processes in this case are rapid, and by the next day the EEG does not differ in character from the background recording, although a slight depression of biopotentials predominates. Nevertheless, by the end of the experiment in this series of animals, generalized synchronized slow-wave activity also develops in all sections with a

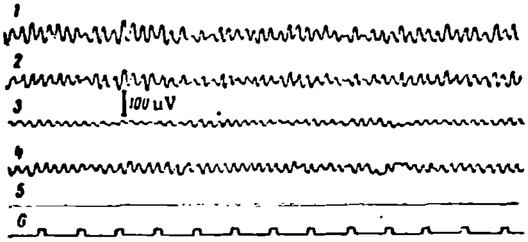


Figure 56. Bioelectric activity of brain structures on the 32nd day of the experiment (noise 120 dB).
Cortex: 1 — cervical, 2 — auditory zones; subcortex: 3 — lateral nucleus of the thalamus; 4 — reticular formation of the mesencephalon; 5 — stimulation mark; 6 — time mark.

frequency of 4-6 Hz which, 30-45 minutes after deactivation of the noise, is replaced by polyrhythmic activity with a predominance of the basic rhythm, but with greatly reduced amplitude in comparison with background activity. /192

Figure 57 shows the dynamics of change in the amplitude of biopotentials of these structures of the brain in experimental animals. As can be seen, a significant reduction of biopotential amplitude is observed, more pronounced with 120 dB noise. The greatest depression appears in nonspecific subcortical structures. By the end of the experiment, the voltage of potentials is somewhat evened out in the cortex as well as in subcortical structures of the brain.

After 36 days of the noise, the character of bioelectric activity was observed. The electroencephalograms of rabbits subjected to the effect of 90 dB noise for 4-7 days were completely restored. With regard to the group of animals experiencing noise with an intensity of 120 dB, even after 18-31 days there was no "reverse" development of electrographic changes. Bioelectric activity continued to be synchronized and slow-wave; a slight increase in amplitude and increased frequency of rhythm to 5-8 fluctuations per second was observed by this time. /193

On the basis of a study of electric reactions of specific and reticular structures of the brain under the influence of various noise stimuli, A. V. Kadyskin

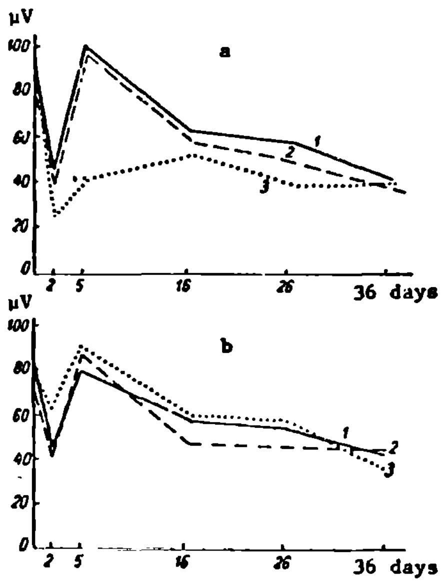


Figure 57. Changes in mean amplitude of biopotentials of the cortex (a) and subcortical structures (b) of the brain for the test period (noise 120 dB)
a: 1 — optic, 2 — sensory-motor, 3 — auditory zones;
b: 1 — reticular nucleus of the thalamus; 2 — lateral nucleus of the thalamus; 3 — reticular formation of the mesencephalon. Vertically — amplitude.

showed that the dynamics of changes detected depends on the intensity and length of the effective noise.

As a result of the effect of noise stimuli, slow low-voltage fluctuations develop in the cortex of the large hemispheres, in the thalamic structures, and in the reticular formation of the brain stem, which evidently indicate the development of an inhibitory condition. In proportion to the effect of the noise, these rhythms become the dominant form of bioelectric activity and are even observed beyond the periods of stimulation. The rhythms of electric activity in these nerve formations of the brain are generally slowed down and depressed. Rhythm synchronized with respiration appears in thalamic structures, the reticular formation of the stem and the cortex of the large hemispheres.

These data on the appearance, development, generalization and reinforcement of orderly synchronized slow-wave rhythm enabled A. V. Kadyskin to assume that evidently the reticular formation of the brain stem participates in the functional shifts detected in various sections of the central nervous system caused by the effect of noise.

There was also interest in the effect of pulse noise on the functional state of the central nervous system.

G. A. Suvorov (1968), in experiments on rabbits with chronically implanted bipolar leads, and with stimulating electrodes in temporal and frontal areas of the cortex as well as the reticular formation of the mesencephalon and hippocampus,

studied the effect of pulse noise in the form of an aperiodic sequence of square pulses with average latency of 2 seconds, square shape (pulse time 10 msec), filled with white noise, with pulses lasting 100 msec (intensity per pulse 100 dB).

The characteristics of the effect of pulse noise were comparatively evaluated with the effect of stable white noise of the same average intensity — 87 dB.

The bioelectric activity was recorded during the entire test. Thresholds of /194 excitability of the brain structures in question were determined before the noise, and then with a single effect of the stimulus, after 1, 3 and 6 hours exposure to the noise.

With threshold high-frequency stimulation of the reticular formation of the mesencephalon, a activation reaction was observed on the EEG which was characterized by desynchronization of the ECG of the frontal area of the cortex, stabilization of the rhythm in the temporal cortex and reticular formation of the mesencephalon. Theta rhythm was recorded in the bioelectric activity of the hippocampus. At the moment of stimulation, this electroencephalographic reaction was accompanied in behavior by an orienting-receptive reflex, which was characterized by movements of the animal resembling those directed toward the best perception of distant stimuli. With slight increase in the amplitude of the stimulating current, tonic tension was observed in the animal, accompanied by turning the head or entire trunk to the ipsilateral side. After the stimulation of the mesencephalic reticular formation ceased, an orienting-investigative reaction was observed in most tests, which was characterized by movement of the animal with searching motions.

When the temporal area of the cortex was stimulated with a current amplitude below threshold, a reaction of awakening was recorded in most tests. With threshold stimulation of this area of the cortex, brief discharges of the aftereffect were recorded in its bioelectric activity which were accompanied by stabilization of rhythm on the EG of the hippocampus and reticular formation. A reaction of alarm was noted in the animals. The data obtained by G. A. Suvorov agree with the research of V. A. Krauz (1968), who studied the relation of behavioral and EEG reactions during stimulation of structures of the forebrain, intermediate brain and the mesencephalon.

Under the influence of pulse noise during the first 5-10 minutes of the test,

a reaction of activation was recorded on the ECG. During the next 2 hours, synchronization of the rhythm was observed on the ECG with periodic spurts of spindles in the frontal area of the cortex, and pronounced disturbance of rhythm stabilization was noted on the EG of the reticular formation of the mesencephalon and the hippocampus. During the third hour of the experiment, a pronounced, persistent reaction of desynchronization was recorded in the bioelectric activity of the cortex which was accompanied by theta rhythm in the hippocampus and "tension" rhythm in the mesencephalic reticular formation. In the next three hours of the test, EEG activation alternated with periodic brief intervals of biopotential synchronization.

An analogous reaction of activation was also recorded on the EEG under the effect of stable noise for 5-10 minute testing; however, during the next 6 hours of the experiment mainly a reaction of synchronization was noted in the bioelectric activity of brain formations. /195

In an hour after the effect of pulse noise, the excitability of the temporal area of the cortex and the reticular formation of the mesensephalon increased markedly. Thresholds of behavioral and attendant EEG-reactions, due to the stimulation of these structures, were reduced 1.5 and 1 V, respectively. After 3 hours of the stimulus, excitability of the temporal, cortex, and the reticular formation was reduced in comparison with the preceding stage of the experiment. However, if the thresholds of induced reactions caused by stimulation of the cortex increased 1 V, the threshold of the activation reaction of the reticular formation of the mesencephalon was increased in comparison with the preceding stage of the test only 0.25 V. After 6 hours of pulse noise, the excitability of the temporal area of the cortex was increased even more, but nevertheless the value of its thresholds was less than after 1 hour of the noise. Reductions in the thresholds of the behavioral and EEG reaction of activation, recorded when the reticular formation was stimulated, were less pronounced than after the first and third hour of the experiment (Figure 58, 59).

Unlike the pulse stimulus, 1 hour after the effect of stable noise, the excitability of the temporal area of the cortex was somewhat decreased, as the threshold of induced reactions increased an average of 0.5 V. This depression of the cortex was noted against a background of induced excitation of the reticular formation of the mesencephalon, in which the threshold of the activation reaction

was reduced 1.25 V in comparison with the control. In contrast to this, after 3 hours of stable noise, the excitability of the cortex was markedly increased in comparison with the control. The thresholds of behavioral and EEG-reactions were reduced an average of 1.5 V. In this case, against a background of induced excitation of the temporal area of the cortex, the thresholds of behavioral and EEG-reactions of activation of the mesencephalic reticular formation were slightly increased in comparison with analogous indices obtained after the effect of stable noise, after 1 hour of testing. The threshold of excitability of the reticular formation of the mesencephalon was an average of 0.25 V lower than the control indices, but in some tests it was identical with the control values.

In the next 3 hours of stable noise, the functional state of the cortex and the reticular formation of the mesencephalon did not essentially change, as the indicies of excitability of these structures was mainly the same as after the third hour of this stimulus. /198

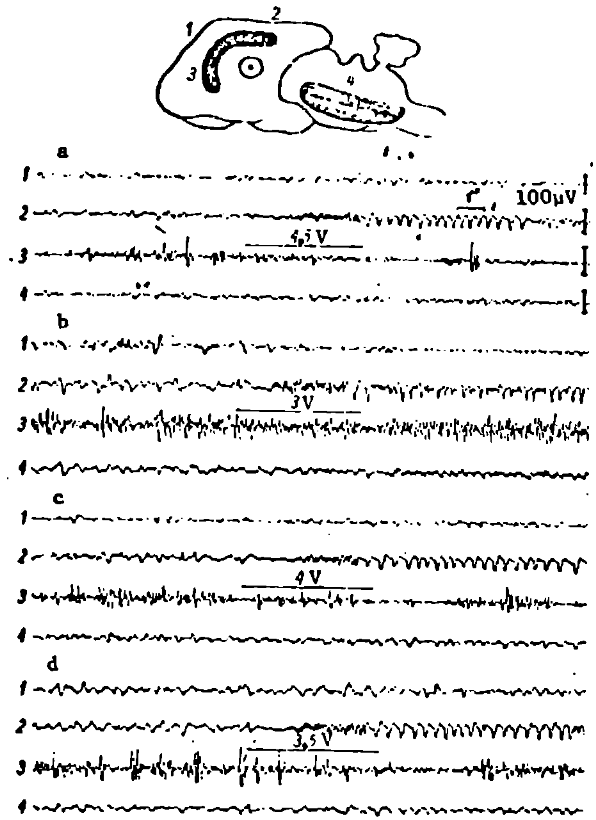
According to the data of F. S. Borodkin (1967) and V. A. Krauz, the excitability of the cortex increases upon threshold stimulation of the mesencephalic reticular formation, while subliminal stimulation of the reticular formation, increasing its activity, leads to a depression of the cortex.

<u>Dynamics of the Bioelectric Activity of Various Sections of the Brain During Rhythmic Light Stimulation Against a Background of Noise</u>

The achievements of modern physiology make it possible to broaden the complex of methods used to interpret more extensively and completely those changes which appear in the central nervous system during noise.

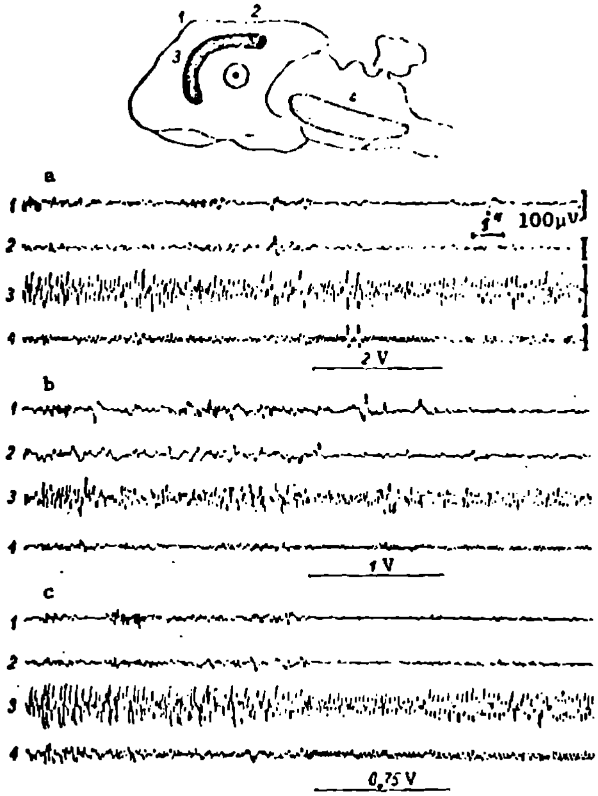
It is known that the method of rhythmical light stimulation has received wide recognition in evaluating the functional state of the brain, both in experimental research and in clinical practice. But, unfortunately, this method has not yet been used to study the functional properties of the nerve structures of the brain under noise conditions.

As far back as 1892, N. Ye. Vvedenskiy designated the speed of those elementary reactions which underlie the vital activity of each cell as "functional mobility"



/196

Figure 58. The effect of pulse noise on the excitability of the temporal area of the cortex.
a — control; b,c,d — 1,3 and 6 hours after the effect of pulse noise. 1 — frontal area of the cortex; 2 — temporal area of the cortex; 3 — hippocampus; 4 — reticular formation of the mesencephalon. Solid line — stimulation period.



/197

Figure 59. The effect of pulse noise on the threshold of the activation reaction of the mesencephalic reticular formation.
a — control; b,c — 1 and 6 hours of the effect of pulse noise.
1 — frontal area of the cortex; 2 — temporal area of the cortex;
3 — hippocampus; 4 — reticular formation of the mesencephalon.
Solid line — stimulation period.

(physiological lability). N. Ye. Vvedenskiy suggested that functional mobility be measured by the largest number of electric fluctuations (corresponding to elementary bursts of excitation) which tissue can generate per unit time, in exact conformity with the rhythm of maximum stimulation. The level of functional mobility, determined by the maximum rhythm of elementary bursts of excitation, and consequently the length of the individual burst of excitation in their sequence, came to be considered by N. Ye. Vvedenskiy as the basic index of the functional state of nerve and muscle tissue.

This is why A. V. Kadyskin (1968) used the phenomenon of the assimilation of the rhythm of light flashes (synonyms: rhythm rearrangement reaction, rhythm sequence reaction, etc.), which as is known consists of the formation of the potentials on the EEG which are synchronized with the rhythm of the stimulus. The concept of the range of assimilation of the rhythms was introduced and the assimilation of upper and lower harmonics of the frequency of stimulation described, which was the beginning of the wide use of the reaction of assimilation of the rhythm of light flashes in experimental and clinical electrophysiological research /199 (M. N. Livanov, 1960; A. G. Kopylov, 1956; N. P. Bekhtereva, 1963, 1965, 1967; V. I. Gusel'nikov, A. Ya. Supin, 1968 and others).

The majority of these works primarily studied the process of the rearrangement of spontaneous activity in the cortex of the large hemispheres to conform with the rhythm of light stimuli, and in only a few of them were processes occuring in subcortical optic centers and reticular structures of the mesencephalon studied, or the role of these structures in processes of assimilating the rhythm of light flashes investigated. The reaction of assimilation of the rhythm is a fundamental electrophysiological phenomenon, making it possible to study the laws of organization of bioelectric rhythm and to use methods of investigating functional shifts in brain structures.

It seemed possible to A. V. Kadyskin to study in chronic experiments rearrangement of the rhythm of electric fluctuations not only in the zones of the cortex, but also in the reticular formation of the mesencephalon, the pons, and in specific and nonspecific systems of the thalamus. Thus, the advantages of chronic experiments enabled A. V. Kadyskin to study the reaction of rhythm assimilation at various levels of the brain directly during noise. Experiments in studying the assimilation of the rhythm of light flashes were conducted in test groups subjected to the effect

of noise with an intensity of 120 and 90 dB, as well as in a control group.

A study of rhythm assimilation was made daily before the experiment, during noise every 15 minutes, and in the after-period, 10, 30 minutes and 1 hour after deactivation of the noise in the entire range of light frequencies from 0.5 to 30 Hz. Length of the stimulus in the various tests was 10 seconds, and the interval between the applied light stimuli was from 15 to 25 seconds. The energy of the bursts in the majority of tests was 0.3 J; illumination was 25 lx. The light was placed 25 cm from the eyes of the rabbit.

He studied the amplitude, frequency, spatial distribution, length of responses, the ratio of responses to basic activity and the ratio of responses of deep structures to the responses recorded in the cortex. Taking into consideration the fact that, in evaluating the functional state of the nerve structures of the brain, it is impossible not to involve parameters of rhythm rearrangement, which are evidently of definite importance and closely connected with lability and excitability, A. V. Kadyskin studied the curves of assimilation of the rhythm of light flashes not only qualitatively, but also quantitatively. The graphs suggested by A. G. Kopylov (1956) were used for a quantitative evaluation. The frequency of flashes per second is plotted horizontally, and vertically — the index of assimilated rhythm (relative length), i.e., the ratio of the length of the interval where /200 assimilation of rhythm is detected to the entire period of rhythmical stimulation (in %). These curves make it possible to determine the following parameters of rhythm assimilation: upper limit, lower limit, range, amplitude and index for any frequency, areas of predominant assimilation of rhythm, degree of irradiation and generalization of response to the application of light stimuli.

In the tests of A. V. Kadyskin, the maximum reproducible rhythm of brain structures of the animals was 10-15 fluctuations per second. In this range, the reactive potentials have a pointed shape; large frequency stimulation caused non-specific changes in the electroencephalographic tracing, expressed by intensification of the basic rhythm.

Light stimuli lying in the 15-30 Hz range caused very weak, barely noticeable rearrangement of the rhythm of background bioelectric activity of brain structures. The assimilation reaction of the rhythm of light flashes was relatively weak in the specific nucleus of the thalamus, and slight rearrangement of the background

rhythm appears in the nonspecific system of the thalamus in response to the effect of rhythmic photostimulation. But here also a reaction of assimilation of the rhythm of light flashes sometimes appeared with the use of infrequent stimuli (2-8 Hz).

Assimilation of the rhythm of light flashes was quite pronounced in the reticular formation of the pons and the mesencephalon. But, nevertheless, reticular structures best reproduce a rhythm which resembles that of its own fluctuations, revealing slight inertia with the application of other frequency ranges. The optic cortex nevertheless always responded with a quicker and more complete reaction of rhythm reproduction with the application of any frequencies of light flashes.

A study of the reaction of assimilation of the rhythm of light flashes in animals subjected to the effect of wide-band stable noise with an intensity of 120 and 90 dB enabled A. V. Kadyskin to find typical differences in the reaction between both groups, as well as in comparing it with the control.

In the first period of noise with an intensity of 120 dB, a pronounced ability to reproduce comparatively frequent rhythms was revealed. Before the tests they were weakly assimilated or not assimilated at all (15, 20 Hz, sometimes 25 and even 30 Hz). This was clearly shown in the cerebral cortex and, especially, in the auditory and cervical areas. A similar tendency was observed in subcortical structures, but there, however, assimilation of light stimuli was limited primarily to the reticular formation of the mesencephalon, pons and reticular nucleus of /201
the thalamus. The lateral, medial, and ventral nuclei of the optic lobe "responded" by rearranging their rhythm to the light stimuli, by accelerating the rhythm and increasing the amplitude of fluctuations.

From the data on the reaction of brain structures to light stimuli during noise of 120 dB on the fifth day of the experiment, we see considerable improvement in the assimilation of higher frequencies whose frequency increases correspondingly; the index of assimilation of light flashes is high compared with the control. We must note that a similar reaction is typical of all structures studied in the cortex as well as in the subcortex.

Changes in the reaction of assimilation of the rhythm of light stimuli during 90 dB noise are aimed in the same direction, however, less distinctly, although

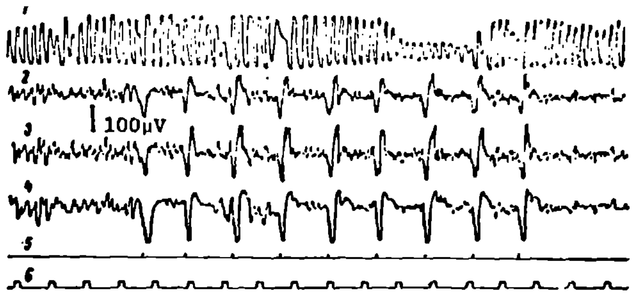


Figure 60. Reaction of assimilation of the rhythm of light stimuli of 0.5 Hz by various brain structures during noise. 1 — pneumogram; EEG: 2 — auditory zone of the cortex; 3 — medial nucleus of the thalamus; 4 — reticular formation of the mesencephalon; 5 — stimulation mark; 6 — time mark (1 sec).

the index of rhythm assimilation is almost the same.

During the experiment, the amplitude of reproducible responses to stimuli is significantly reduced. Instances of separation of responses of light stimuli were also determined, which were assimilated by brain structures which were very pronounced in the cerebral cortex and reticular structures at a photostimulation frequency from 5 to 12-16 Hz. It could be ascertained that the response reaction to light stimuli in the first experiments developed immediately after their application. At this time, rhythm assimilation in all brain structures of low frequencies is markedly decreased (Figure 60), but assimilation of higher frequencies clearly /202
improves (15 Hz or more).

In proportion to the course of the experiment, the process of assimilation of the rhythm of light flashes became pronounced in all structures of the brain being studied. A rhythm of 20 fluctuations per second began to be reproduced, which is intensified by the structures of the cortex and by reticular structures of the brain stem, as well as by lateral and reticular nuclei of the optic lobe. The fact of improved assimilation of more frequent rhythms and reduced assimilation of infrequent rhythms of light flashes before the 5-6 days of the noise effect (with 120 dB noise) was very pronounced.

This indicates that, in a given functional state of the cortex and subcortical structures, their lability is strongly increased. High fluctuations of light flashes are more adequate for this state, as a result of which they are reproduced by both cortical and subcortical specific and nonspecific structures. During this period of the sound effect, in passing from the application of high frequencies of light flashes to infrequent ones, the cortex stops responding by rearranging its electric activity and does not assimilate the rhythm of the stimulus, while before the noise this led to improved reproduction of infrequent light stimuli. The auditory and sensory-motor areas of the cortex respond to light stimuli almost the same as the optic zone of the cortex, which was not observed before the sound. Thus, in the first period of sound (1-5 days) a deterioration of assimilation by the cortex of slow rhythms of light flashes (0.5-8 Hz) is observed, and a pronounced improvement in the assimilation of more frequent rhythms with simultaneous broad involvement of the entire cortex in assimilating rhythms, as well as the reticular structures of the brain stem.

These data indicate that, under the effect of noise, the lability of the cortex and subcortical structures increases. This is indicated by the broadening of the range of assimilated frequency, the assimilation of the rhythm of light flashes by these structures, and the appearance "on the spot" of a response reaction to the application of light stimuli. Generalization of response reactions, in turn, emphasizes the close connection and interdependence of brain structures in the response reaction to the noise.

Subsequently, distinct changes occur in the assimilation of the rhythm of reply flashes, indicating the gradual reduction of lability of nerve formations of the brain. This is seen in the fact that the range of assimilated frequencies is reduced significantly, and the rearrangement of the assimilation of rhythms in the cortex, if it does take place, is limited to the optic and often the auditory region. It is gradually revealed that the brain structures of the cortex and the /203 subcortex have stopped assimilating frequent fluctuations (15-25 Hz), while the amplitude of more infrequent fluctuations is markedly reduced and the length of the latent period of responses pronounced. At the same time, instances of generalization begin to disappear. In proportion to the course of the experiment, besides the reduced assimilation of the rhythms of light fluctuations of more frequent ranges, the brain structures — especially the reticular formation of the mesencephalon, lateral and reticular nucleus of the thalamus — gradually began to

respond better to more infrequent fluctuations with a frequency of 5-8 per second, which were not assimilated before. The amplitude of assimilated potentials progressively dropped. By the 12-16 day, processes of assimilation of the rhythm of light flashes underwent very definite changes. By this time, the range of assimilated frequencies was significantly constricted, limited primarily to basic rhythm fluctuations (5-8 fluctuations per second). The cerebral cortex, especially the optic and auditory areas, have not yet lost their ability to respond to the more frequent stimuli (10-12 Hz). However, the sensory-motor area hardly reacts at all to stimulation of any ranges, responding only with a slight increase of activity or development of slow, irregular fluctuations. The reticular formation of the mesencephalon and the pons also significantly loses the ability to assimilate applied stimuli.

Often a generalized reaction of rhythm assimilation to light stimuli of the 4-6 Hz range appeared in all the nerve formations of the brain under study; the greatest amplitude of fluctuations was observed in structures of the reticular formation of the brain stem. At this time, the dependence of the response reaction to light flashes on the character of the recorded bioelectric activity was revealed. If stimuli with a frequency of 5 Hz are applied against a background of slow-wave fluctuations, they lead only to increased electric activity, but — when fluctuations of 10-12 Hz are present in the background photostimulation of this range — they led to distinct assimilation of rhythm.

These effects in accelerating the rhythms of photostimulation indicate that the sections of the brain under study "responded" to a narrow frequency range of light stimuli between 4-6 Hz. The lability of the cortex at these times was significantly reduced, which is indicated by the fact that there were often reactions to rhythmical light of various frequency ranges similar to those to continuous light, i.e., brief reaction of desynchronization appeared. The amplitude of these assimilated rhythms remained low, slightly increasing in comparison with the background. /204

During sound, from test to test and especially in the earlier stages when the depression of some autonomic functions of the organism began to appear, it could be observed very often that the amplitude of induced potentials and the severity of the reaction of rearranging electric activity was the same with the effect of light stimuli whose frequency ranges are quite different. Often, more frequent responses develop to low frequencies in the auditory and cervical zones of the

cortex and in the reticular formation of the mesencephalon and pons.

In proportion to the development, reinforcement, and generalization of slow-wave synchronized activity, distinct changes also occurred in the reaction of rearranging rhythm. As was pointed out above, synchronized activity with a frequency of 2-4 Hz developed in all the nerve formations studied. In the first periods of the appearance of this rhythm, brain structures were still responding to light fluctuations in the 1-6 Hz range, with a long latent period, low index of assimilation and low amplitude. Both zones of the cortex and subcortical structures reacted uniformly to more or less frequent rhythms, very slightly changing the basic background of electric activity; the amplitude of the fluctuations increased slightly.

By the 18-21st day of the experiment, it could be definitely observed that light flashes of the range used (0.5-30 Hz) caused almost no changes in background activity, leading only to a slight acceleration of electric fluctuations, which were always more pronounced at the start of the test. Even at this time and later, it could be clearly ascertained that there was no assimilation of the rhythm of light flashes, neither in the zones of the cortex, nor in nonspecific and specific systems of the thalamus, nor in the reticular structures of the brain stem. Photostimulation did not depress the rhythm, — on the contrary, synchronization of rhythm was slightly intensified and biopotential amplitude increased. Even this insignificant reaction was often observed only in the first stimulations of the test.

Thus, in the second period (after 6-8 days) the range of assimilated frequency was significantly constricted; it was limited primarily to basic rhythm fluctuations, with less pronounced instances of generalization, with significant reduction in the amplitude of induced potentials, etc. At the concluding stage of the test, almost complete absence was noted of the sequence of rhythm of light stimuli in the brain structures studied.

A study of the reaction of assimilation of the rhythm of light flashes by nerve formations of the brain of animals subjected to noise with an intensity of 90 and 120 dB revealed essential differences in both experimental groups. /205

In the first days of the experiment on animals with noise of 90 dB, A. V. Kadyskin found nearly analogous changes with the application of light stimuli of various frequency ranges, i.e., assimilation of fluctuations of more frequent

ranges was significantly improved. Later, in the reaction of the rhythm sequence, a reduced ability to assimilate light stimuli of high frequencies (15-25 Hz) appeared first in the sensory-motor area of the cortex, then in a nonspecific and specific system of the thalamus and, subsequently, in the reticular formation of the mesencephalon and pons. These phenomena, as a rule, appeared in the second half of each experiment and were more pronounced by the end when not only the range of assimilated frequencies was significantly constricted, but their amplitude was markedly reduced with simultaneous increase of the latent period.

These changes in the rearrangement of the rhythm of brain structures to light flashes under the effect of 90 dB noise had a very pronounced transitory character. 15-20 minutes after the noise was deactivated, any pronounced changes, in comparison with the original ability of the brain structures to react to light flashes of various frequency ranges, could barely be noted in the assimilation of light flashes. The amplitude of induced potentials remained low; however, it also was restored by the next day of the experiment. Following the brief distinct increase in the ability of brain structures to "assimilate" a wider range of light flashes, there appeared a significant reduction in lability, expressed by constriction of the range of assimilated light stimuli, which was limited to fluctuations of the basic rhythm, and by a reduced index of assimilation.

Thus, the effect of a wide-band stable noise with intensity of 90 and 120 dB for a long period of time (36 days) causes definite changes in the reaction of brain structures to light flashes of various frequency ranges, indicating a disturbance to the functional state of the central nervous system. The use by A. V. Kadyskin of the method of discontinuous photostimulation enabled him to trace not only changes in the functional state of the cortex, but subcortical structures as well and gave him an idea of the cortical-subcortical relationships during noise, as well as the degree of participation of various sections of the brain in the response reaction to noise.

The reactivity and the lability of the cortex and subcortical structures decreases in proportion to the sound, which is indicated by the sharp reduction in /206 the range of assimilated frequencies, the increased latent period, reduced index of assimilation of light flashes, and disappearance of generalization processes, which is, evidently, related to the decreased excitability of the reticular structures of the brain stem. Rhythmical photostimulation helped reveal the phase condition

developing in the central nervous system during the noise. The weakest of the sub-cortical formations studied were the reticular structures (reticular formation of the mesencephalon and pons, reticular nucleus of the thalamus and the specific nucleus of the thalamus), a general "station" for switching all somatosensory fibers on their way to the cortex. These structures are the first to lose the ability to reproduce given light stimuli.

Biochemical Changes In The Central Nervous System During Noise

In the presence of rather extensive material, obtained with the use of physiological methods of research, there are few works dealing with biochemical changes in the central nervous system during noise. Analyzing literature data and taking the latter into account, it becomes evident that brain structures do not remain unchanged.

S. V. Alekseyev and Kh. A. Getsel (1968) made an attempt to use autoradiography to study the penetration of the hematoencephalic barrier (HEB) by tagged phosphorus and the exchange of phosphorus compounds in brain structures with single and repeated noise. Rats were subjected to the effect of white noise with an intensity of 100 dB. The authors established that, as a result of the white noise, a sharp increase in penetrability in the temporal area of the hemispheres and in the horn of Ammon (hippocampus) appears in rats (Tables 35 and 36). After a brief exposure of P^{32} (15 minutes) a large amount of tagged phosophorus penetrates into these areas from the blood. However, with a single effect of white noise, in a day the disturbed function of HEB penetrability was restored.

With prolonged (38 days) white noise on rats, disturbances of HEB became persistant. In a series of tests lasting 15 minutes, maximum specific activity (SA) of the temporal area (Table 36) was observed in comparison with other structures of the brain.

The autoradiograms of tests lasting 1 day (Table 37) also differed from corresponding autoradiograms of the control rats. The author suggests that exact correspondence of blackened sections of the autoradiogram with individual histological structures can be explained by the dissimilar rate of the inclusion of tagged phosphorus in proteins and nucleic acids of various histological structures.

TABLE 35

THE EFFECT OF ONE HOUR OF NOISE ON THE DISTRIBUTION OF P^{32} IN BRAIN STRUCTURES OF RATS

Histological Structure	Specific activity (SA X 10^4 pulses/mm^3) in tests of varying length		
	15 minutes	control	1 day
Areas of the cortex:			
limbic	170	144	209
cervical	152	74	142
parietal	152	73	—
temporal	107	74	149
piriform	66	74	163
Horn of Ammon (hippocampus)	110	78	152
Base of brain stem	21	24	—
Hypothalamus	97	175	—
Mesencephalon	—	—	70

TABLE 36

THE EFFECT OF 38 DAYS OF NOISE ON THE DISTRIBUTION OF P^{32} IN BRAIN STRUCTURES OF RATS

Histological Structure	Specific activity (SA X 10^4 pulses/mm^3) in tests of varying length	
	15 minutes	1 day
Areas of the cortex:		
limbic	85	
cervical	68	
parietal	68	142
temporal	152	
piriform	78	
Horn of Ammon	93	155
Base of brain stem	44	—
Hypothalamus	119	—
Mesencephalon	—	140

TABLE 37

THE DISTRIBUTION OF P^{32} IN BRAIN STRUCTURES 2 WEEKS AFTER 38-DAY EFFECT OF NOISE /208

Histological Structure	Specific activity ($SA \times 10^4$ pulses/mm^3) in tests of varying length	
	1 hour	1 day
Areas of the cortex:		
limbic	86	100
cervical	74	103
parietal	74	103
horn of Ammon (dors. part)	—	98
temporal	61	112
piriform	82	163
Horn of Ammon	124	
Horn of Ammon (vent. part)	—	152
Hypothalamus	244	—
Mesencephalon	—	100

In 1 day after a 38-day noise session ended, the SA of all brain structures was relatively uniform. The SA of all areas of the cortex was 142.10^4 pulses/mm^3; the mesencephalon — $140 \cdot 10^4$; and slightly higher in the horn of Ammon — $155 \cdot 10^4$ pulses/mm^3. This also differs sharply from the control autoradiogram, obtained in a test lasting 1 day.

Thus, the diffuse distribution of blackening density in the autoradiogram and the similar values of the SA of the cortex of the hemispheres, the horn of Ammon and the mesencephalon possibly indicate a general reduction in the intensity of the exchange of macromolecular phosphorus compounds in brain structures following repeated noise.

In 2 weeks after the repeated effect of noise, HEB disturbances were not completely normalized in the area of the horn of Ammon or the limbic area.

A. I. Vasil'yev (1956), studying cell respiration in the central nervous system during experimental otitis and the effect of sound stimuli with a level of intensity of 80 and 120 dB, found decreased oxidizing and reducing ability of the brain. The fact is interesting that these changes were not evident when an emulsion of

turpentine (to develop otitis) was introduced into the tympanic cavity of animals in a state of narcosis. This proves the participation of the central nervous system in the formation of response reaction to stimulation of the peripheral receptor. Similar results were also obtained by the author with sound after preliminary x-raying of the animals. Radiation, evidently, causes supraliminal inhibition in the central nervous system, and therefore reduces the reaction of /209 the organism to a sound stimulus.

V. N. Vorontsov (1968) and L. A. Marakushkin, having used biochemical methods of research in the brain during the effect of sound, helped broaden our concepts of intimate processes which occur in the central nervous system under the effect of this stimulus. The close connection between the state of exchange processes in nerve tissue and the functional state of the central nervous system is well known. The high sensitivity of the brain, especially the cortex of the large hemispheres, to lack of oxygen leaves no doubt about the decisive role of oxidizing processes in the functional activity of the nervous system. This is indicated by the parallelism between the morphological development of the central nervous system and the maturing of oxidation enzymes in ontogenesis. Thus, tissue respiration of the brain is an important index of the state of the central nervous system. Taking this into account, V. N. Vorontsov (1968) conducted a study of tissue respiration of the brain during the effect of noise — a factor primarily acting on the nerve centers. The experiment was conducted on white rats (males). All animals were kept on a well-balanced mixed diet.

The animals were subjected to the effect of noise in a soundproof chamber. Wide-band stable noise (30-16,000 Hz) with levels of intensity of 115 and 85 dB was used. Tissue respiration was determined by the Warburg method. The author conducted the tests with the sound stimulus lasting various lengths of time. Tissue respiration was studied in the following formations of the brain: cortex — temporal, parietal, cervical areas, as well as the thalamic area, hypothalamus and colliculi.

The author showed that during 10-minute exposure to noise with an intensity of 115 dB (Table 38), a reliable increase in oxygen consumption appears in the cortex of the temporal and parietal areas and in the colliculi ($P < 0.05$). The most pronounced difference from the control is in the cortex of the parietal area: 11.73 ± 0.37 ml/hr (in the test) against 10.47 ± 0.26 ml/hr (in the control).

No reliable changes were found in the thalamic area, the hypothalamus, or the cortex of the cervical area. When the length of the effect was increased to 30 minutes, a more marked increase in the activity of respiration was found in all areas of the brain under study, the most pronounced in the cortex of the temporal area (10.67 ± 0.28 ml/hr). Thus, when exposure is lengthened to 30 minutes, further intensification of respiratory activity occurs in brain tissue. This process, having first developed in the cortex of the temporal and parietal areas and in the colliculi, is distributed to neighboring parts of the brain. With noise stimulation for 1 hour, changes in respiratory activity of the brain are less pronounced. With the effect of noise for 3 hours, a decrease in tissue respiration was expressed in the majority of investigated areas (in the test: cortex of temporal area 7.48 ± 0.32, cortex of parietal area — 8.57 ± 0.29, cortex of cervical area 9.28 ± 0.32; in the control, respectively: 9.04 ± 0.24; 10.47 ± 0.26; 10.88 ± 0.27). Shifts in the subcortical areas of the brain were less pronounced. With 85 dB noise, analogous but less pronounced changes were found (Table 39). Of interest is the fact that noise with an intensity of 85 dB in three hours of exposure does not cause marked changes in the activity of respiration. These appear only with a six-hour effect of this noise. This phenomenon indicates a slower response reaction of the organism to less intense stimulus. /210

In tests with noise intensity of 115 dB and with repeated stimulation, 2 hours after the effect, more pronounced reduction of tissue respiration was observed than with a single effect. The greatest reduction in the activity of respiration was observed in the cortex of the temporal area (6.4 ± 0.22 O_2 ml/hr). With long exposure to noise of 1 month, a tendency toward normalization of tissue respiration is typical. With this time of exposure reliable changes are found only in the cortex of the parietal and temporal areas. In rabbits subjected to noise for 3 months, significant statistically-reliable reduction of tissue respiration is noted in all areas studied. The greatest reduction in respiration activity is found in the cortex of the temporal area (5.3 ± 0.46 ml/hr). With prolonged noise with an intensity of 85 dB, depression of respiration was expressed to a lesser degree (Table 40). It is also typical that a month's exposure to this noise not only did not cause pronounced shifts in tissue respiration, but also caused a slight tendency toward increased respiratory activity of subcortical formations.

TABLE 38

TISSUE RESPIRATION OF THE BRAIN (O_2 ml/hr) DURING THE EFFECT OF NOISE WITH AN INTENSITY LEVEL OF 115 dB*

Section of brain	Time of exposure								
	Control	10 mins.	30 mins.	1 hr.	3 hrs.	Control	2 weeks	1 mth.	3 mths.
Cortex of temporal area	9,04 ± 0,24	9,95 ± 0,30	10,67 ± 0,2	10,06 ± 0,26	7,48 ± 0,32	8,60 ± 0,23	6,40 ± 0,27	6,76 ± 0,33	5,40 ± 0,46
Cortex of Parietal area	10,47 ± 0,26	11,73 ± 0,37	12,06 ± 0,24	11,2 ± 0,26	8,57 ± 0,29	10,19 ± 0,22	7,82 ± 0,35	8,16 ± 0,43	7,19 ± 0,43
Cortex of cervical area	10,88 ± 0,27	11,19 ± 0,3	12,19 ± 0,37	12,0 ± 0,30	9,28 ± 0,32	11,13 ± 0,27	9,44 ± 0,2[illegible]	10,44 ± 0,40	7,68 ± 0,38
Thalamic area	0,12 ± 0,28	9,66 ± 0,27	10,1 ± 0,32	10,02 ± 0,29	7,98 ± 0,31	9,31 ± 0,26	8,61 ± 0,33	8,92 ± 0,30	7,39 ± 0,37
Hypothalamus	9,67 ± 0,25	9,68 ± 0,34	10,69 ± 0,29	10,38 ± 0,32	9,4 ± 0,3	9,54 ± 0,23	9,93 ± 0,35	10,05 ± 0,34	7,9 ± 0,36
Colliculi	8,22 ± 0,22	8,91 ± 0,27	9,04 ± 0,23	8,93 ± 0,25	7,48 ± 0,25	8,45 ± 0,2	7,56 ± 0,36	8,93 ± 0,30	6,96 ± 0,27

*Commas represent decimal points.

/210

TABLE 39

TISSUE RESPIRATION OF THE BRAIN (O_2 ml/hr) DURING SINGLE EXPOSURES TO NOISE WITH AN INTENSITY LEVEL OF 85 dB*

Time of exposure	Section of the brain					
	Cortex of temporal region	Cortex of parietal area	Cortex of cervical area	Thalamic area	Hypothalamus	Colliculi
Control	9,11±0,24	11,13±0,28	1[illegible],28±0,24	9,45±0,29	9,38±0,26	8,09±0,21
1 hour	10,35±0,28	12,09±0,30	12,33±0,26	10,43±0,29	9,99±0,24	8,79±0,27
3 hours	10,03±0,27	10,08±0,33	10,65±0,23	9,76±0,30	9,78±0,26	8,63±0,30
6 hours	7,76±0,30	9,88±0,26	10,52±0,33	8,57±0,29	8,88±0,29	7,57±0,23

TABLE 40

TISSUE RESPIRATION OF THE BRAIN (O_2 ml/hr) AFTER PROLONGED NOISE OF 85 dB*

Time of exposure	Section of the brain					
	Cortex of temporal area	Cortex of parietal area	Cortex of cervical area	Thalamic area	Hypothalamus	Colliculi
Control	8,81±0,27	10,77±0,29	10,54±0,28	9,14±0,30	9,44±0,31	7,97±0,22
2 weeks	7,26±0,26	8,65±0,25	10,2±0,33	3,24±0,28	8,96±0,33	7,64±0,35
1 month	7,65±0,36	9,96±0,38	11,05±0,32	9,69±0,36	8,93±0,36	8,67±0,26
3 months	6,48±0,33	8,65±0,31	9,77±0,36	7,89±0,34	8,12±0,35	6,97±0,35

*Commas represent decimal points.

/112

In animals subjected to noise for 3 months, 9-10 days after it ended, a tendency was observed toward normalization of respiration. This was especially pronounced with noise of 85 dB. A typical characteristic is restoration of the function of tissue respiration during noise of 85 dB in the cortical section of the acoustic analysor. Further stimulation with noise of this intensity leads to significant changes in tissue respiration. In connection with this, such an intensity must be considered to affect the central nervous system.

Comparison of tissue respiration during the effect of various octave bands of noise showed that the character of changes in respiratory activity of the brain depends not only on the intensity, but also on the frequency characteristics of the noise.

A study of the activity of oxidizing processes in the after-effects period showed that, in spite of the large percent of changes in the cerebral cortex, restoration of the function of respiration there is quicker. This is evidently connected with the higher organization of the cortical section of the brain and the flexibility of its adaptational system. And, on the other hand, subcortical sections, being more inert in relation to processes of excitation and inhibition and their underlying complex transformations, reveal more stable changes of intimate processes. In animals subjected to noise for 3 months, the ability to summarize subliminal pulses was tested every 2 weeks according to the method of S. V. Speranskiy (1965). The method is distinguished by its great accuracy. Its principle lies in determining the minimal electric current causing a motor reaction in the animal — a test which is widely used in physiological research.

The parallelism between changes in tissue respiration and the functional state of the central nervous system is established. These changes in tissue respiration and the significant increase in the summation-threshold index indicates the development of persistent inhibition in the central nervous system.

It can be assumed that the state of tissue respiration of the brain is connected with changes in respiratory enzymes. To prove this hypothesis, the author conducted a study of the activity of respiratory enzymes — succino-dehydrogenase and cytochromoxidase in the cortex and stem part of the brain. One group of animals was subjected to noise with an intensity of 115 dB for 1 hour, 3 hours, 2 weeks (3 hours per day), the second to noise of 85 dB for 1 hour, 6 hours and 2 weeks. /213

The activity of cytochromoxidase was determined by the Vernon method (1911) in the modification developed by V. N. Vorntsov, the activity of succino-dehydrogenase, by the method of Kuhne and Abud.

During repeated exposures to noise of both intensities, phase changes were found in the cortex of the brain. After 1 hour of the noise, an increase is found in the activity of cytochromoxidase; after 3 hours and 6 hours — a reduction. Noise with an intensity of 115 dB caused more significant changes; in the stem part of the brain, these were less pronounced. Changes in the activity of succino-dehydrogenase after an hour were insignificant, but after 3 and 6 hours they were expressed to a greater degree than the changes in cytochromoxidase. With 2 weeks of exposure to noise, the change in the activity of enzymes was still greater.

Thus, it was shown that a change in the total consumption of oxygen is parallel to the tissue activity of the enzymes, which indicates disturbance during noise stimulation of subcellular structures, particularly mitochondria which are a depot of cellular energy resources.

S. V. Alekseyev and V. N. Vorontsov conducted tests studying the effect on tissue respiration of the brain of octave bands of noise with a level of intensity of 100 dB. The tests were conducted during a single effect for 5 hours.

Analysis of the data obtained, conducted by the authors, revealed that the most pronounced changes in tissue respiration during the effect of octave bands of noise are observed in the temporal area. With the effect of an octave band of 300-600 Hz, oxygen consumption was 9.4 ml/hr, at 1200-2400 Hz it was 8.7 ml/hr, and with the effect of 4800-9600 Hz band it was 8.2 ml/hr, while oxygen consumption in the control group of animals averaged 10.3 ml/hr. In the parietal area during the effect of noise of octave bands 300-600 Hz and 1200-2400 Hz, a slight reduction in tissue respiration was observed, and with the effect of 4800-9600 Hz band, reduction of oxygen consumption by tissues of the brain in the parietal area was 15% higher in comparison with the control group of animals. Similar data were also obtained in analyzing changes in tissue respiration of the cervical area during exposure to noise of the above indicated octave bands.

In the colliculi during the effect of noise of the 300-600 Hz band oxygen consumption by the tissues of the brain was 7.7 ml/hr (in the control group /214

oxygen consumption in the colliculi was 8.7 ml/hr).

The results of data obtained by S. V. Alekseyev and V. N. Vorontsov showed that reduction of oxygen consumption is directly dependent on the appearance of high-frequency components in the noise spectrum.

L. A. Marakushkin conducted analogous research with pulse noise with an intensity of 85 dB in pulses with a recurrence frequency of 30 per minute and an on-off duty factor of 1. Duration of exposure was 1, 3 and 6 hours. he second series of tests, the duration was 10, 30, 60 days (3 hours daily). In the noise period lasting from 1 and 3 hours to 10 days, an increase of oxdizing processes was noted in the animals in all the sections of the brain studied. During the effect lasting 6 hours and 60 days, oxygen consumption was reduced, while when the animals spent 30 days under this noise, no essential deviations were found. Thus, the effect of both pulsed and stable noise on tissue respiration of the brain has a phase character — stimulation alternates with inhibition. The stimulation phase during the effect of pulse noise is long, with an inclination toward wide irradiation, and in this it differs from stable noise.

A comparative study of the effect of pulse periodic noises (G. A. Suvorov and L. A. Marakushkin, 1970) and pulse aperiodic and stable noises of equal medium intensity (90 dB) and the same spectral composition on the rate of oxygen consumption showed that these noises affect tissue respiration of the cerebral cortex of white mice differently. Pulse noise, both periodic and aperiodic, has greater stimulating ability than stable noise (pertains especially to pulse, aperiodic noise). If a comparatively insignificant reduction in the intensity of oxygen consumption of brain tissue was noted during a month's exposure to stable stimulus, with the same exposure to pulse aperiodic and periodic noises, the oxygen consumption was increased.

They obtained interesting data in determining the activity of the enzymes cytochromoxydase and succino-dehydrogenase. They found that the activity of enzymes during prolonged noise is reduced. Their material implies that there is an interconnection between oxidizing processes in the brain and enzyme activity. Tables 41 and 42 give the activity of these enzymes in relation to the time of the noise.

TABLE 41

ACTIVITY OF ENZYMES, EXPRESSED IN PERCENTAGES IN RELATION TO THE CONTROL (CONTROL — 100%), DURING IMPULSE NOISE WITH AN INTENSITY OF 85 dB IN ACUTE TESTS

Enzymes	Time of exposure to noise, hrs.					
	1		3		6	
	Sections of the brain					
	Cortex	stem	cortex	stem	cortex	stem
Cytochromoxydase	116	113	110	117	87	92
Succino-dehydrogenase	120	113	116	114	89	87

TABLE 42

THE ACTIVITY OF ENZYMES, EXPRESSED IN PERCENTAGES IN RELATION TO THE CONTROL (CONTROL — 100%), DURING IMPULSE NOISE WITH AN INTENSITY OF 85 dB IN SUBACUTE TESTS

Enzymes	Time of exposure to noise, hrs.							
	1		10		30		60	
	Sections of the brain							
	cortex	stem	cortex	stem	cortex	stem	cortex	stem
Cytochromoxydase	110	117	113	112	92	95	80	87
Succino-dehydrogenase	116	114	118	115	88	90	75	81

CHAPTER V

NOISE SICKNESS

The opinion first expressed that noise has an effect on the organism as a whole (Ye. Ts. Andreyeva-Galanina, 1957) and causes noise sickness has now been verified in a number of works (B. A. Krivoglaz, A. A. Model' et al., 1967; V. Ye. Lyubomudrov and others). /216

Data were presented in the section, "The Effect of Noise on the Human Organism" (Chapter III), which indicate that the central nervous system, its autonomic section, and the cardio-vascular system are affected much earlier than the organ of hearing. Numerous observations and clinical data indicate that the dominance of specific symptoms and syndromes is determined by the character, intensity and spectral composition of the noise, as well as the individual sensitivity of the person.

Clinical symptoms during the effect of noise can be divided into specific, which develop in the peripheral section of the organ of hearing (Corti organ), and nonspecific, which develop in various organs and systems of the organism.

Numerous experimental studies indicate, without doubt, a connection between reactions observed in the organism and the effective noise as stimulus.

Functional disturbances of the autonomic section of the central nervous system and of the cardio-vascular system are especially notable nonspecific reactions.

B. Z. Krivoglaz, A. A. Model' et al., (1967) distinguished three syndromes of noise sickness: 1) vaso-autonomic dystonia; 2) hemicrania; 3) diencephalic syndrome.

E. A. Drogichina and L. Ye. Milkov distinguish four basic syndromes: 1) autonomic-vascular dysfunction; 2) astheno-autonomic syndrome; 3) hypothalamic syndrome; 4) syndrome of dyscirculatory encephalopathy.

Depending on the character and intensity of the noise, the syndromes can be expressed differently, and in many cases, certain symptoms can be generally absent.

Clinical observation. Subjective symptoms. In examining workers subjected to the effect of noise, we notice a large number of complaints of irritation, headaches, memory failure, drowsiness, increased fatigue, etc., which increase /217
with job experience. During the effect of high-frequency noise with an intensity of 140-150 dB, pain was noted in the eyes and ears, a feeling of anxiety and general tension.

According to the numerous studies of E. A. Drogichina and L. Ye. Milkov with workers systematically subjected to the effect of noise with a level of 95-120 dB, dull headaches were most often noted, frequently localized in the forehead area. They develop primarily at the end of work or afterwards, sometimes upon agitation; pain in the area of the heart, emotional instability, increased fatigue, sleep disorders (interrupted sleep, insomnia, less frequently drowsiness), depressed appetite, heightened sweating, memory failures, dizziness (usually in the form of "darkening in the eyes" when changing the position of the body).

Table 43 gives, as an example, the frequency of complaints of machine operators and metal workers who are affected by stable noise with an intensity of 80-85 dB during work, and Table 44 gives the same for pistol firers (82-87 dB) and sub-machine gunners (96-99 dB).

In comparing the frequency of individual complaints noted by machine operators, we see a difference in their expression. If the greatest percentage in the first group falls in poor sleep and headache, a significant percentage of those of pistol shooters and submachine gunners are irritability and fatigue, which is related to the effect of very intense noise on the second group of examinees.

TABLE 43

FREQUENCY OF BASIC COMPLAINTS OF MACHINE OPERATORS AND METAL WORKERS AGED 21-40 YEARS (AFTER N. N. POKROVSKIY)

Complaints	Absolute Number	%	Complaints	Absolute Number	%
Increased fatigue	26	8.6 ± 1.6	Poor sleep	70	23.1 ± 2.3
Irritability	34	11.2 ± 1.8	Headache	41	13.6 ± 2.0
Pain around the heart	26	8.6 ± 1.6			

There are distinctive features about the character of the headaches. They appear primarily at the end of the working day, at times, accompanied by noise and ringing in the ears, localized in the temporal-forehead area. The headache passes in 2-3 hours, but sometimes lasts longer. Complaints of dizziness are less frequent, primarily from pistol shooters. They often complain of irritability, fatigue, weakness, pain around the heart, emotional lability — they lose self-control at nothing. We see no correlation between reduced auditory function and autonomic syndromes or complaints about the heart.

B. A. Krivoglaz, A. A. Model' et al., noted headaches, dizziness, increased irritability, and insomnia among workers in winding shops.

Ye. B. Reznikov (1966) detected functional disorders of the nervous system in a large number of stampers subjected to the effect of pulse noises; these became more pronounced as the time working under industrially noisy conditions increased. The author found a large number of complaints from workers in this occupation, — in the case of pulse noise with an intensity of 109-129 dB, — of headaches (78%) of various localization, most often in the forehead and temporal areas, which were often accompanied by nausea. They developed at the end of the working day and lasted several hours. In 11.5% of cases, headaches lasted longer.

TABLE 44

FREQUENCY OF BASIC COMPLAINTS OF SUBMACHINE GUNNERS AND PISTOL SHOOTERS

Complaints	Pistol shooters		Submachine gunners	
	Absolute number	%	Absolute number	%
Headache	68	60.7	37	61.6
Dizziness	28	25	12	20
Fatigue, weakness	43	38.4	35	58.3
Irritability	51	45.5	30	50
Emotional lability	36	32.1	8	13.3
Sleep disorders	27	24.1	11	18.3
Pain around the heart	46	41	15	15
Palpitation	23	20.5	5	8.3
Pains in the epigastrium and dyspepsia	30	26.8	10	16.6
Decreased hearing	19	16.9	10	16.6
Weight loss	—	—	6	10
Increased perspiration	25	22.3	23	38.3

In 37.8% of stampers, dizziness was observed, primarily after work and when turning the body quickly accompanied by tachycardia; they indicate the undoubted effect of noise on the vestibular apparatus. An analogous phenomenon was noted by B. A. Krivoglaz, A. A. Model' et al. According to their data, excitability of the vestibular analysor was most often increased in workers in noisy factories and was very seldom decreased; sometimes, asymmetry was observed in the chronaxy indices used to determine the state of excitation of this analysor in workers in the weaving industry.

Analyzing the frequency of individual complaints of the workers, we can see /219
that the parameters of noise and its nature are undoubtedly very important; this especially pertains to the intensity of noise. When it is increased, the frequency of complaints, particularly of general irritability, increase. However, not only is intensity important, but the nature of the noise as well. Pulse noise of the same intensity as stable noise causes more negative emotions than the latter.

N. N. Pakrovskiy found that 171 out of 995 workers in machine construction factories that he examined had distinct symptoms of the "irritable weakness"

syndrome. The main symptoms, according to the data of L. V. Gakkel' (1960), S. N. Davidenkov (1960) and A. Kreyndler (1963) are: asthenia, headaches, and sleep disturbances. Many of those suffering the irritable weakness syndrome indicate that industrial noise bothers them very much, especially random noise, — an engine unexpectedly starting up, a heavy metal object falling to the floor. Noises at home are especially irritating. There is hardly enough basis to assume that noise is the only etiological factor in the development of the irritable weakness syndrome, but it undoubtedly plays a leading role.

We must not ignore the role of individual reactivity, but we can hardly attribute the most importance to it.

N. N. Pokrovskiy (1968), besides the group of metal workers, examined 224 spinning factory workers (1), 292 workers in conditioning and winding shops (2) and 229 people in a third group (3). The first group worked in conditions of 100 dB noise with maximum energy at 50-500 Hz; the second, in low-frequency noise conditions (maximum energy at 150-300 Hz) with an intensity of 90 dB; the third worked in conditions with a noise level of 80 dB and maximum energy in the 50-400 Hz range. Table 45 lists the complaints noted in the workers he examined (aged 21-40 years).

The importance of noise intensity in the frequency of individual complaints is also clear in this occupational group working in a noisy industry.

Figure 61 gives the number of persons having the irritable weakness syndrome in three age groups of workers in the spinning industry.

E. A. Drogichina and L. A. Kozlov (1957) also observed the irritable weakness syndrome in workers in many noisy industries, as well as emotional instability, reduced attention and memory. Recently, several researchers have raised the question of the possible combined effect of two related mechanical factors — noise and vibration. This question is particularly valid, as from a phylogenetic standpoint their role in knowing the world was very similar.

If at lower stages of development of organisms intercourse with the surrounding world occurred — and in some it still does — by means of contact receptors (vibration receptors-pacchionian bodies), highly-organized representatives become

TABLE 45

THE FREQUENCY OF COMPLAINTS OF WOMEN WORKERS IN THE SPINNING INDUSTRY (AFTER N. N. POKROVSKIY)

Nature of Complaints	Intensity of noise, dB					
	100		90		80	
	Number of examinees					
	196		212		169	
	Frequency of complaints					
	abs.	%	abs.	%	abs.	%
Increased irritability	32	21.9±3.4	26	12.2±2.2	21	12.4±2.5
Headaches	62	41.9±4.1	32	15.1±2.5	10	5.9±1.8
Dizzyness	27	18.5±3.2	35	16.5±2.5	2	1.1±0.3
Pains around the heart	12	8.2±2.2	11	5.2±1.5	13	7.6±2.0
Noise, ringing in ears	4	2.7±1.3	4	1.4±0.7	1	0.6±0.4
Increased fatigue	27	18.5±3.2	7	3.3±1.2	2	1.1±0.8
Poor sleep	18	12.3±2.7	21	9.9±2.0	7	4.1±1.5

familar with the world of sounds through distant receptors — organs of nearing.

Therefore, it is possible to expect an increased effect of vibration with noise, or of noise with vibration. In this respect, the data of N. N. Pokrovskiy are interesting about the frequency of complaints of those subjected to the effect of noise only, and noise combined with vibration. Complaints of increased irritability and perspiration are noted most often with the combined effect of vibration and noise, while other complaints are essentially the same. With the effect of the two factors, the irritation syndrome was observed more often (37.1 ± 4.7%) than with only noise (26.6 ± 6.5%).

G. I. Zuyev (1969) and M. L. Khaymovich (1961), having examined trimmers and nailers, found a large percentage of complaints of irritability, perspiration, and sleep distrubances in the first group. The intensity level of the noise during trimming work was between 118-121 dB, and during operation of the machines in the nailing shop — 96-103 dB, but the noise trauma was longer. The frequency of complaints and objective symptoms increased with work experience.

Objective syndromes and symptoms. In conducting neurological examinations, a number of authors find no organic damage in the central and peripheral nervous

system, but clinical data of Soviet occupational pathologists indicate the possibility of their development. /221

Sometimes a listless reaction is observed in cranial nerves. Such a listless reaction of the pupils of the eye to light was noted by G. Z. Kumdina in pistol shooters and submachine gunners, and also inadequate convergence and slight nystagmoid twitchings. However, these symptoms are noted in isolated individuals, and can hardly be presented in connection with the effect of noise only. More indicative are the changes in the reflector sphere — increased tendon-periosteal reflexes accompanying the general psychomotor reaction. Table 46 gives the frequency of individual syndromes detected in examining pistol shooters and submachine gunners.

The electroencephalographic research conducted on workers by E. A. Drogichina, L. Ye. Milkov and E. D. Cinzburg (1963, 1965) showed typical changes in the bioelectric activity of the brain indicated in the synchronization of potentials (agravation of alpha rhythm, appearance of slow waves). The authors also conducted laboratory studies with the effect of noise (110 dB) on the subjects. The changes they detected led them to assume that they are connected with weakening of the activating effects of the reticular formation on the cerebral cortex, which is verified by the research of A. V. Kadyskin.

Bugard et al. (1957) recorded flattened electroencephalograms, almost devoid of alpha activity, in engine testers.

Very important in pistol shooters and submachine gunners is tremor of the fingers of the extended hand (42-30%) and of the eyelids (32.1-26.5%), distal (32.1-50%) and general 22.3-33.3%), hyperhydrosis, as well as dermographia — bright, persistent (70.4-50%). However, these percentages can be different in other groups of workers.

Ye. B. Reznikov noted more pronounced reactions in the autonomic nervous system in examining stampers. In particular, dermographia was noted in 53.6% or more, tremor — in 47.9%, instability in the Romberg position — in 45.2%.

L. V. Fasler (1928), studying the state of the health of nailers, working in conditions of intense noise, found in 106 out of 200, signs of functional depression of the central nervous system (diffusion, lapses of memory, mental fatigue,

TABLE 46

RESULTS OF NEUROLOGICAL EXAMINATION OF PISTOL SHOOTERS AND SUBMACHINE GUNNERS (AFTER G. Z. DUMKINA)*

Neurological symptoms	Pistol shooters		Submachine gunners	
	abs.	%	abs.	%
Listless reaction of pupils of the eye to light and accomodation	5	4,4	2	3,3
Inadequate convergence	4	3,6	2	3,3
Asymmetry of facial innervation	6	5,3	1	1,6
Nystagmoid	6	5,3	3	5
Increased tendo-pereostal reflexes:				
in hands	28	25	11	18,3
in feet	22	19,6	7	11,6
Reduced tendo-pereostal reflexes:				
in hands	4	3,5	10	16,6
in feet	8	7,1	10	16,6
Listlessness, lack of abdominal reflexes	6	5,3	6	10
Tremor of fingers of extended hand	48	42	18	30
Tremor of eyelids	36	32,1	16	26,6
Instability in the Romberg position	15	13,3	13	21,6
Distal hypalgesia	5	4,4	4	6,6
General hyperhidrosis	25	22,3	23	38,3
Distal hyperhidrosis	36	32,1	30	50
Dermographia, intense, persistent	50	70,7	30	50
Acrocyanosis	4	3,5	4	6,6
Trophic changes in the skin	12	10,7	10	16,6
Increased muscular excitability	6	4,4	4	6,6
Khvostek symptom	39	34,8	20	33,3
Symptom of oral automatism	11	9,8	6	10

*Commas represent decimal points.

depression, apathy and listlessness, decreased attention). Analogous functional disturbances of the nervous system of the neurasthenia type were discovered by M. L. Khaymovich (1960) in this occupation.

Depression of the autonomic nervous system is more pronounced in workers subjected to the effect of noise with an intensity of 120 dB than in those working under noise conditions with a level of 95–100 dB. The inhibiting reaction, characterizing the preclinical phase of the effect of the noise factor on the /223 organism, evidently largely reflects the compensatory-adaptational reaction of the organism.

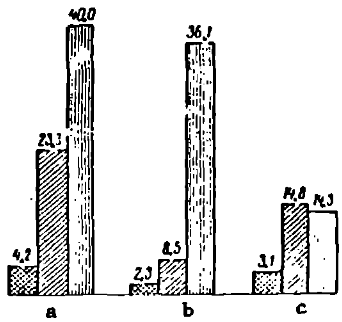


Figure 61. The number of workers suffering the irritable weakness syndrome (in % of the number of examinees).
a —medium-frequency noise 100 dB;
b — low-frequency noise 90 dB;
c — low-frequency noise 80 dB.
Columns with crosshatching — under 20 years; with diaganol shading — 21-40 years; with straight shading — over 40 years of age.

Thermoregulatory processes are often disturbed under the influence of intense noise. The possibility of skin temperature being increased in conditions of intense noise is indicated by the research of S. S. Vishnevskiy and S. I. Gorshkov (1960) and others. The frequency of changes in body temperature, according to the data of S. V. Alekseyev and G. V. Suvorov (1965), rises in proportion to the increase of noise intensity.

M. L. Khaymovich (1960), studying the thermoregulatory reflex in riveters according to Shcherbak's method, found a change in many cases. According to the data of B. A. Krivoglaz, A. A. Model', B. G. Boyko, L. A.Zaritska (1967), D. P. Kachalay, P. D. Volokh (1964), "temperature-mosiac" type changes were often found in the skin topography of temperature, less often distal hypothermia and thermoasymmetry of the hemi-type were observed. Thermoasymmetry as a nonspecific symptom of the effect of noise is also indicated by A. P. Rusinova (1965) and other authors.

At the same time, changes are detected in the skin-galvanic reflex of those subjected to the effect of intense noise (L. P. Bruzhes and A. A. Arkad'evskiy, 1956; A. I. Vozhzhova, 1960; Ye. Ts. Andreyeva-Galanina et al., and others).

Study of the oculocardiac Aschner reflex in workers in "noisy" industries conducted by many authors (L. F. Fasler, 1928; T. A. Orlova, 1958; I. Dimov et al., 1960; L. Ye. Milkov, 1963a, and others) revealed a change in cardiac reactivity, often with a paradoxical reflex (lack of pulse reaction), sometimes with a distorted reflex. The frequency of such shifts rose in proportion to the increased intensity of the noise. The orthostatic reflex can increase also (A. I. Vozhzhova, 1969, and others). Hyporeactivity of sympathic sections of the nervous system is noted in workers with long work records, which is expressed in depression of the pilomotor reflex (E. A. Drogichina, 1957, and others), weakening of skin reaction

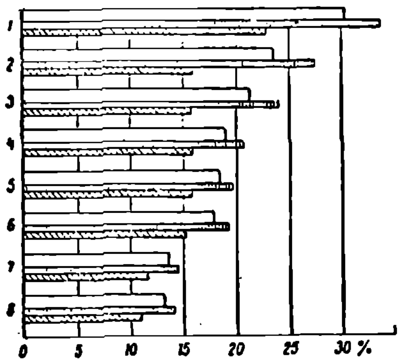


Figure 62. Autonomic disturbances in workers in noisy occupations (after Jansen).
Vertically: 1 — skin (pale); 2 — vascular disorders; 3 — heart condition; 4 — and 5 — changes in the mouth cavity and nasopharynx; 6 — disturbance of equilibrium; 7 — status varicosus; 8 — Khvostek reflex.
Columns: white — all changes; with diagonal shading — noise ranges I and II; with straight shading — noise ranges III and IV.

in response to intradermal injection of adrenalin (L. Ye. Milkova, 1963a), and lack of pulse reaction during study of the orthoclinostatic reflex.

Among autonomic symptoms, Jansen (1959) pointed out pallor of the skin and mucous membranes (Figure 62).

Determining the time of the latent period of the dermographia reaction does not show essential changes, but its length can be shortened (to 1-2 minutes, instead of the normal 2-6), which indicates a tendency of the capillaries toward spasm. This is also indicated by the weak reaction. The use of adrenalin-histamine testing shows the lability of the vascular reaction of the skin. /224

Many researchers noted subcortical reflexes in several groups of workers — Khvostek, Khobotkov, Marinesco. The presence of these indicates existing functional disturbances of the nervous system.

It has already been indicated above that 4 basic syndromes are arbitrarily distinguished, depending on clinical characteristics and the severity of noise pathology (E. A. Drogichina and L. Ye. Milkov).

Clinical symptoms, indicating functional changes in the nervous system, can often appear in evidently healthy individuals who have worked for a long time under intense noise conditions. These include: reduction or (more rarely) increase of tendon reflexes, slight tremor of the fingers of an extended hand, depression of the palatal, swallowing, conjunctival and corneal reflexes, reduction of abdominal reflexes, unsteadiness in the Romberg position, general hyperhidrosis and chilling of hands and feet, increased mechanical excitability of the muscles, positive symptom of Khvostek, slight enlargement of the thyroid gland.

E. A. Drogichina and L. Ye. Milkov found in workers, including obviously healthy individuals, who had been subjected to the effect of 95-120 dB noise for a long time, increased functional activity of the thyroid gland with radioactive iodine (I^{131}), which primarily indicated functional rearrangement of the organism. In test conditions, an analogous level of noise, even with a brief effect, caused significant disturbances in the activity of endocrine glands of laboratory animals — adrenals, pituitary gland, thymus and sex glands. Experiments of Bugard (1955, /225 1958) on dogs and rabbits during the effect of intense noise (130 dB) for 12-24 hours also indicate increased functional activity of a number of endocrine glands — adrenal cortex, the anterior lobe of the pituitary gland and the thyroid gland. Deviations in the state of the analyzing functions are noted, including the skin analysor, as well as vascular instability.

Functional disturbances of the nervous system can be either the hypersthenic or hyposthenic type of neurosis in connection with other neurosis-like symptoms, including regional vascular disorders. The following case history can serve as an example of the initial symptoms of functional disturbances of the nervous system with an autonomic-vascular dysfunction course.

Patient K-va, 33 years old, spinner, with 11 years experience working in noise conditions. She works 8 hours per day.

She entered the clinic with complaints of frequent headaches, irritability, increased fatigue, distrubed sleep (insomnia alternating with normal sleep and increased sleepiness during the day), reduced hearing, shortness of breath while walking rapidly and climbing stairs, cold feet. She had suffered about 3 years. The disease had developed gradually from periodic headaches.

Past diseases: frequent colds, occasional tonsillitis, in childhood — malaria, pneumonia, mumps.

Neurologically, a lack of swallowing and palatal reflexes. Slight smoothing of the right nasopharyngeal fold. Slight deviation of the tip of the tongue to the right. Tremor of the eyelids and slight tremor of the fingers of the extended hands. Tendon reflexes lively, uniform, with the exception of increased knee reflexes. Abdominal reflexes were evenly reduced, toe reflexes were absent. Slight hypalgesia of the "high gloves" and "socks" type. Slight depression of cold,

tactile and vibration sensitivity in the hands and feet. Pilomotor reflex is depressed. Pale pink dermographia, disappearing in 15 seconds. Hands and feet cold.

Capillaroscophically — symptoms of spastic-atony. Aschner reflex — 84/76, orthoclinostatic reflex — 84/92/84, arterial pressure — 115/65.

Blood, urine and gastric juice analysis was normal. EKG — semihorizontal distribution of the electrical axis of the heart. Consultations with the gynecologist, therapist or pathological oculist were not indicated. The optical floor is normal. Study of thyroid function did not reveal any deviations.

The sugar curve is "double-humped," with a slow recovery time; a moderate reduction of tissue circulation was noted with the use of radioactive sodium.

Diagnosis: autonomic-vascular dysfunction against a background of asthenic reactions. Slight bilateral hearing reduction of the cochlear neuritis type.

Treatment was conducted with bromine with caffeine, dibasol, proserine, vitamins B_1 and C, pine baths, ionization with $CaCl_2$.

As a result of the treatment, sleep was normalized, headaches decreased, the extremities became warmer, feeling in the feet was restored. She was allowed to return to work.

A pronounced asthenic (astheno-autonomic, astheno-neurotic) syndrome, connected with the effect of noise, is observed less often, usually with long work experience under conditions of intense noise (120-130 dB). /226

In a number of industries, in connection with specific work and episodical or brief intense noise (jet engine testers, etc.), hearing difficulties might not appear. In such cases, a complex evaluation of the state of the nervous and cardio-vascular system is very important in clinical observation and work examination. However, because of the nonspecificity of the neuro-vascular syndrome, extreme care must be exercised in settling these questions, expecially if it is a matter of the systematic effect of noise of lower intensity (95-100 dB).

Patient M., 36 years old, driver with 12 years experience working with noise. The ailment developed gradually after 8 years of working under noisy conditions. He was troubled with headaches, poor sleep, pain in the stomach, combined with fatigue. Past diseases — malaria in childhood, gastritis. He smokes as many as 20 cigarettes a day. He is not an abuser of alcohol.

Upon admittance, he complained of frequent headaches in the forehead area, ocassional pains around the heart, increased irritability, listlessness in the morning and increased fatigue, perspiration, depressed appetite, aching in the feet while resting. Emotional lability was noted, sleep disturbances with frequent nightmares. Pupils were rather narrow, S = d; pupil reaction to light, convergence and accomodation were satisfactory. The right nasopharyngeal fold was smooth. Palatal reflex was reduced. Slight tremor of the fingers of outstretched hands and sweating in the Romberg position. Moderate hypoesthesia in the distal sections of the hands and feet. Reduction of vibration sensitivity, slight in the hands and pronounced in the fingers and the back of the feet. Tendon reflexes in the hands torpid, S = d, knee reflexes lively. Abdominal reflexes are quickly exhausted. Hands are moderately cyanotic, feet are colder than the hands. Pronounced underarm hyperhidrosis, hands and feet moist. Spastic-atony of the capillaries. The skin of the body is dry, mucous membranes are pale. Local red dermographia is absent. Reduced erythema in response to intradermal injection of histamine and adrenaline. Khvostek symptom is weak (+). Thyroid gland is increased to I-II stage. Study of its function with radioactive I^{131} revealed significantly increased activity (17.6% — after 2 hours; 45.1% — after 24 hours).

Blood and urine analysis showed no pathology. Roentgenoscopy of the thorax normal. Arterial pressure — 140-90. Optic floor normal.

Analysis of gastric juices showed a lack of free acid and a reduction (20) of general acidity. The reduction of tissue circulation during Aldrich testing was also studied with radioactive solium. Blood chlorides 445 mg%, cholesterol — 230 mg%, amount of prothrombin — 97%, lipoid phosphorour — 7.6 mg%, converted to lecithin — 190.0 mg%. Total protein of blood serum — 8.62%, albumin, 5.07%, alpha-globulin 0.49%, beta-globulin 0.97%, gamma-globulin 1.36%, A/G coefficient — 1.43.

Study of ENT organs — no hearing loss detected. The patient was given a

complex of general strengthening and sedative treatment; physiotherapy and thyroid treatment were applied. Improvement was noted. In 2 months he was transferred (according to the sick leave certificate) to a job without noise and vibration, anbulatory and sanatorium treatment was continued.

However, the treatment was not permanent. After returning to his former job, the condition again deteriorated, and after repeated examination at the Institute he was placed in a job which excluded the noise-vibration factor. /227

Diagnosis: astheno-autonomic syndrome with neurotic reactions and symptoms of hyperthyroidism in connection with the effect of intense noise.

This case is typical of the possibility of the gradual development of functional disorders of the nervous system with no disturbance of hearing sensitivity.

According to the data of E. A. Drogichina and L. Ye. Milkov, they also occasionally observed typical diencephalic autonomic-vascular crises in persons whose work is connected with the effect of intense noise combined with neuropsychic tension.

In these individuals, usually against a background of an asthenic condition, combined with increased sensitivity of a number of analysors, there developed cardiac, cerebral, or general autonomic-vascular crises. In some cases, a reduction of hearing was noted, and in others, an increase.

Patient Z., 48 years old, technician. Subjected to intense noise for 22 years while testing airplane engines.

The disease developed gradually. After 11 years of work, he began to note headaches, and aching around the heart, of an episodical nature. For 2-3 years before admittance, the state of his health had deteriorated, headches and a feeling of heaviness in his head became constant, for which he repeatedly turned to medical help. A sudden noise at work caused a paroxysm of pains around the heart, accompanied by sweating.

He was kept in the local hospital for 2 weeks, where no pains were observed. However, subsequently, he was not able to work at his job, as noise provoked pains

around the heart.

Upon admittance, a pronounced astheno-neurotic condition was noted in the patient: constant headaches in the forehead area, heaviness in the head, increasing during agitation of prolonged conversation in noisy conditions; pains in the area of the heart with irradiation to the left arm and hand: emotional lability, poor spirits (fits of weeping), sleepiness during the day, aches in the feet at night (revealed by cooling). Symptoms of hyperacusis. Orbital opening d < S. Pupils S = d, narrowed, with satisfactory reactions to light and convergence. Swallowing and palatal reflex reduced. Sweating in the Romberg position. Pereostal and tendon reflexes lively, S = d. No pathological reflexes. Slight reduction of vibration sensitivity in distal sections of the hands and feet. Feet somewhat cold. Pilomotor reaction increased. Dermographia pale, shortened. Aschner reflex — 66/68. Orthostatic reflex — 68/76. Ap — 130/75 (humeral), 70/41 (temporal), temporal-humeral coefficient — 0.54.

A reduction was noted in the latent period of ultraviolet erythema, reduction of the erythemal reaction in response to the intradermal injection of histamine and adrenaline, a tendency of the capillaries toward spastic-atony, contraction of the small arteries in the retina, pronounced slowing down of tissue circulation in a study with radioactive Na^{24}.

On the EKG — indications of slight changes in the myocardium. ENT organs; slight reduction of hearing sensitivity in the area of high-frequency reception (4096 and 2048 Hz) from the left.

Blood, urine and gastric juice analysis showed no pathology. Blood chlorides — 457 mg% (NaCl), cholesterol — 285 mg%, prothrombin — 83%, lipoid phosphorus — 6.2 mg%, converted to lecithin 155.0 mg%, total protein content in serum — 8.92%, albumin — 4.84%, alpha-globulin 0.44%, beta-globulin 0.86%, gamma-globulin /228
1.89%. A/G coefficient — 1.19.

The following case history presents an instance of cataleptic seizures developing during prolonged intense noise of a stable level (114-122 dB).

Patient F-ov, 54 years old, foreman of a ball-bearing shop. 25 years spent working under noise conditions.

During the last 2-3 years, the patient had experienced sudden attacks of weakness in his legs while walking, and had more than once fallen in the street. There was no loss of consciousness; there was no difinite relation of these attacks to an emotional factor.

A number of autonomic-vascular dysfunction type deviations was noted in the patient (pains around the heart, irritability, troubled sleep, etc.). Tremor is observed in the fingers, a reduction of all tendon reflexes with anisoreflection of knee reflexes (d < S). No abdominal reflexes are provoked except a medium abdominal reflex. Slight hypoesthesia of pain and cold sensitivity in the hands and feet, more pronounced reduction of vibration sensitivity in the hands, and especially in the feet. Cold feet. Local dermographia weak changing to white. Erythemal reaction in response to intradermal injection of histamine and adrenaline reduced. Spastic-atonal state of the capillaries. Ocular floor normal. Oculo-cardiac reflex — 68/88. Orthostatic reflex — 68/76. AP — 125/75 (humeral) and 70/45 (temporal). Temporal-humeral coefficient 0.56.

The EKG shows slight sinus tachycardia and horizontal location of the electrical axis of the heart. A slight change in intra-precordial and intra-ventricular conductance. A heightened reaction of the skin to ultraviolet radiation is noted.

Sugar curve is double-humped, blood chloride — 444 mg% (NaCl), cholesterol — 430 mg%, lipoid phosphorus — 10.1 mg%, converted to lecithin — 252 mg%, amount of prothrombin — 88%, Ca content — 9.4 mg%, K — 18.1%.

In studying hearing, moderate bilateral deafness of the cochlear neuritis type is found.

Treatment included belloid, dimedrol, injections of proserine, vitamin B_1 and symptomatic therapy. While he was in the clinic, no severe paroxysms were experienced by the patient.

Thus, the patient with occupational hearing reduction during the prolonged effect of intense high-frequency noise experienced weakness attacks of the cataleptic type. The hypothalamic character of these attacks is largely indicated by disturbances found in studying certain aspects of metabolism (shifts in the state of protein and carbohydrate exchange, increased lipides and cholesterol in

the blood); the participation of the hypothalamic region was also indicated by the shortening of the latent period of ultraviolet erythema and other signs.

We do not exclude the possibility that vascular disorders in the hypothalamic area itself and possibly cortical disorders are at the root of existing damage.

Organic forms of pathology of the nervous system (encephalopathy) are observed in exceptional cases and only in those connected with testing motors where intense noise, exceeding 120-130 dB for a long time, can cause changes similar to air trauma. This form is practically never encountered now. /229

Analysis of archive material has shown that the development of organic forms of pathology is preceded by a period evidencing the clinical pattern of functional damage to the nervous system (E. A. Drogichina and L. Ye. Milkov).

Encephalopathy caused by the prolonged effect of intense noise has no specific characteristics and does not differ from encephalopathy of different etiology (traumatic, toxic, hypertonic). Dominant in the clinical pattern are a persistent pain syndrome, astheno-neurotic, vascular and psychosensory disturbances, signs of hypothalamic inadequacy, organic symptoms (nystagmus, nystamoid, inadequacy of 7th and 11th pairs of cranial nerves, "spotty" or distal type sensitivity disturbances; possible epileptiform attacks). Hearing is not always affected.

It is typical that, when the worker is removed from contact with the noise, attacks do not recommence, which, to a large degree, indicates the vascular origin of these disturbances.

The use of various methods to study the functional state of the central nervous system has given an idea of those complex processes which develop as a result of the noise stimulus. N. N. Pokrovskiy determined the threshold of the electric sensitivity of the visual analysor to determine the resistance of the nervous system of workers in noisy factories. Two groups were selected: one included workers suffering the syndrome of irritable weakness, the second was neurologically healthy. Besides the symptoms already noted, objective observations were made in the first group of a perverted Erben's reflex, namely — acceleration of the pulse on squatting down with the head bent downward. Normally, as is known, the pulse slows down.

The initial thresholds of electric sensitivity of the visual analysor in those suffering the irritable weakness syndrome are lower than in healthy individuals, which agrees with other symptoms noted in this group of workers. The nature of the change in electrical sensitivity varied: in some it was increased after a sound load; in others — it was reduced. Thus, using this method, it was possible to establish, in some cases, the presence of an inhibitory process in the cerebral cortex (with increased threshold), and in others — an excitory process (reduced threshold).

The material obtained by N. N. Pokrovskiy suggests the use of this method in preliminary medical examinations to predict the development of noise sickness. It is especially important in admitting workers under 18 years of age to noisy shops. /230

The greatest changes in electrical sensitivity of the eye are observed in those workers who work under pulse noise.

Data on the state of the autonomic nervous system of workers in noisy occupations were obtained by many occupational pathologists (E. A. Drogichina, L. Ye. Milkov, M. L. Khaymovich, and others). In examining workers under intense noise conditions, E. A. Drogichina found reduced excitability of autonomic sections of the nervous system, inertia of autonomic-vascular reactions, depression of dermographia, pilomotor and several unconditioned reflexes.

G. Z. Dumkina, studying the state of several autonomic reactions, particularly the oculocardiac and ortho- and clinostatic reflexes, in the same way as B. A. Krivoglaz, A. A. Model' et al., found various directions of the reactivity of the workers tested. Reactions in some examinees might be adequate, but excessively strong, in others — distorted, and in still others — lacking or not strong enough.

In studying the oculocardiac reflex, a tendency was noted toward depression of the reaction, variously expressed in different groups of workers, due in particular to different parameters of the noise. With adequate, but distorted reactions, acceleration of pulse is observed instead of slowing down. In studying the clinostatic reflex, on the other hand, slowing down of the pulse rate was noted. The orthostatic reflex most often remained normal.

L. A. Zaritskaya, using ortho- and clinostatic testing, noted most often an inadequate reaction of arterial pressure (increased systolic pressure during ortho-testing and a reduction during clino-testing).

E. A. Drogichina (1957), in examining airplane motor testers, noted a syndrome of irritable weakness, characterized by considerable fatigue, decreased working capacity, emotional instability, reduced attention, memory and other symptoms. In 45 — 30% of the examined individuals, subjected to the effect of intense noise (130 dB), an analogous "noise syndrome" was also noted by other researchers.

During the prolonged effect of noise, Bugard, Souvras and Salle' (1957) found vascular hypotonia, loss of weight, muscle weakness and several shifts in the hematogenic system (moderate eosinopenia and neutropenia, relative lymphocytosis, anemia). /231

A comparison of the data of G. Z. Dumkina with that obtained by B. A. Krivoglaz, A. A. Model' et al., convinces us of their agreement. They also found deviation from normal in pulse rate and in the dynamics of arterial pressure, indicating dysfunction of the autonomic nervous system with predominance of the tone of its sympathetic or parasympathetic sections.

Ye. Ts. Andreyeva-Galanina, A. V. Kadyskin and O. M. Rukavtsev used the method of determining the galvanodermal reflex to evaluate the condition of the autonomic nervous system in sewing machine operators working under the effect of noise (97-105 dB) with maximum sound energy between 4000-8000 Hz. A rapid drop in the electric resistance of the skin is observed in newer workers, reaching 10-25% of the original amount at the end of work shift. The galvanodermal reflex, as is known, is considered to be a component of the total autonomic reaction of the organism, accomplished through the sympathetic nervous system.

M. L. Khaymovich also determined the thermoregulatory reflex (according to Shcherbak as modified by Terner) in nailers to evaluate the state of the autonomic nervous system. The longer the work, the more pathological were the changes. Most often observed was its reduction or inertia. Functional disorders occuring in workers subjected to the effect of noise very clearly depend on the spectral character of the noise, especially on its intensity. Lesser changes are caused by low-frequency noise and medium- and high-frequencies below 80 dB. Disturbances

to the central nervous system are characteristic of the astheno-autonomic or astheno-neurotic syndrome and vascular-autonomic disfunction (L. Ye. Milkov, 1960). In isolated cases the author observed migraine-like syndrome and vestibulopathy, which was noted by B. A. Krivoglaz and A. A. Model'. His data suggests that asthenic and neurotic sympotoms are usually combined with changes in the acoustic analysor. However, this is not always so, and a pronounced disturbance of the acoustic function appears later than change in the functional state of the central nervous system.

Astheno-autonomic, astheno-neurotic syndromes and autonomic-vascular dysfunction are characteristic of noise pathology. Besides their being established in workers of noisy industries by L. Ye. Milkov (1963), they were also noted in other noisy occupations by M. L. Khaymovich, N. N. Pokrovskiy, G. Z. Dumkina, Ye. B. Reznikov and others. That noise is a factor leading to the development of /232 functional disorders in the central nervous system is indicated by the progression of neurological symptoms with work experience. This is verified by the research data of M. L. Khaymovich (1960) and Ye. B. Reznikova, who determined the latent period of the conditioned motor reflex (to strong and weak light stimulus). The first determination was made in nailers, the second in stampers. The first were affected by noise with an intensity of 100-102 dB, and the second — by 109-129 dB. Both authors noted lengthening of the latent period of a conditioned motor reflex to both strong and weak light stimuli with increased work experience. In nailers, the average values of the latent period for a strong light with work experience less than 5 years was 262 relative units; with work experience up to 10 years — 299 units. They were correspondingly greater for a weak light.

This phenomenon was also observed by Ye. B. Reznikov. In stampers with up to 5 years work experience, the latent period was 429 msec, and up to 10 years it was 449 msec for a strong light; for a weak light it was 455 msec, and 486 msec, respectively. Thus, as the years of work increased, the length rises markedly. The latent period also lengthened during the course of the day. Without doubt, this all indicates change in the mobility of cortical processes and pathological inertia.

Pathological vascular reactions in response to a thermal stimulus are detected in persons subjected to noise during work: 1) adequate, but extremely severe reactions — constriction to cold and dilation to heat; 2) adequate but weak; inadequate, perverse reactions when vessels are dilated during the effect of

cold and constricted during heat; 4) lack of reaction and 5) wave reactions during the effect of heat when alternation of pressor and depressor reactions was observed (B. A. Krivoglaz, A. A. Model' et al., 1967). The authors indicate that the nature of the vascular reaction indicated disturbed strength, evenness, and mobility of nerve processes and was similar to that observed in neurotics.

T. A. Orlova (1958) noted in jet engine testers (noise with an intensity of 140 dB), in the majority of cases, significant changes in blood pressure, its increase, or vice versa, its decrease. L. A. Zaritskaya found arterial hypotonia (in 1/9 of the examinees), and asymmetry of arterial pressure (systolic and diastolic) in spinners. She obtained interesting data in regional measurements of arterial pressure (state of temporal-humeral coefficient). Examining spinners and weavers, the author found an increase in 44.5% and an decrease in 19.4%. The degree and expression of these changes were different. Most often (50%) a /233
deviation from normal ratios was found in all arteries examined. For example, asymmetry or reduced arterial pressure is noted combined with increased pressure in the lower extremities and changes in the temporal-humeral coefficient. Less often, the author noted (20%) changes in vascular tone only in certain arteries, for example disturbance of true ratios between pressure in the vessels of upper and lower extremities, or asymmetry in the humeral arteries combined with a reduced temporal-humeral coefficient. L. A. Zaritskaya considered these changes to be a moderate degree of vascular tone damage. Much less frequently in this group of workers there were changes only in one particular vascular area — in temporal, humoral arteries, or those of the skin, considered by the author as slight shifts in vascular tone.

In workers in weaving and spinning shops of the weaving-spinning industry (noise is high-frequency at a level of 94-101 dB) I. A. Benyumov (1963) found arterial pressure depended on the functional state of their nervous system. In obviously healthy individuals the change in arterial pressure was seen in 13.4% of those examined; of these, 8.7% had hypotonia, 1.7% — hypertonia and in 3.0% asymmetry of the arterial pressure index was observed. With functional changes of the nervous system, hypotonia was 9.2%, hypertonia — 3.0%, asymmetry — 3.8%. Hypotonia was most often seen in newer workers (9.4%), hypertonia increased in proportion to the longer work experience in noise (from 1.7 to 3.4%), asymmetry of arterial pressure was primarily noted in the medium-stage group. Hypotonia was most often observed in the spinners (12%), in the weaving factory workers it was noted in only 7.5%; asymmetry of arterial pressure indices was noted in the spinning

factory workers in 5.2%, and in the weaving factory — 2.5%.

N. N. Shatalov, O. A. Saytanov, and K. V. Glotova (1962) examined spinning factory workers who were subjected to the effect of medium and high-frequency noise (400-6400 Hz) with an intensity of 85-95 dB, and workers in a "ball" factory, where the noise background was more intense (114-120 dB) with the same spectral composition. They observed both an increase (in 7.6% of cases) and a decrease of blood pressure (in 12.3%). The most pronounced changes in vascular tone were seen in workers during testing under load. Immediately after the load, the authors observed increased minimum and mean pressure, as well as increased oscillator index, which indicated a hypertensive reaction. Pressure was restored in 3 minutes after the load, and even had a tendency toward reduction. After the working day ended, a decrease in maximum and mean pressure was observed in the workers. /234

In analyzing the electrocardiograms, the authors found several changes in rhythm and intraventricular conductance. Sinus bradycardia or bradyrhythmia was observed in 45.2%, intraventricular conductance (QRST) was on the upper limit of normal or slowed down; less often they noted a reduction and a smoothing out or two-phase character (±) of deflection T, recorded in 2 or more leads.

Later N. N. Shatalov, V. Ye. Ostapkovich and N. I. Ponomareva (1968) conducted an analogous examination of the state of the cardio-vascular system in workers of other factories, working in conditions of the same noise parameters. Change in the state of blood pressure, according to their data, occurs earlier than hearing difficulties. From this the authors conclude that in the development of occupational deafness the role of vascular damage is not excluded.

A. P. Rusinova and L. P. Radionova (1968) examined the condition of the cardio-vascular system in workers in the rope twisting industry. The authors conducted observations for 8 years. The workers were subjected to the effect of intense (92-117 dB) medium- and high-frequency noise. Persons working in noise conditions with an intensity of 95-117 dB often had functional changes in the cardio-vascular system; a higher level of mean hemodynamic pressure, as well as lability in performing tests under load. The most unfavorable indices were in workers over 40 years of age. Hypertonic disease was encountered twice as often in them as in workers of the same age, who worked in more favorable conditions. Hypertonic

disease assumed a more serious course in these people; in 5 it was complicated by coronary disturbances. In workers over 40, deviations in lipide exchange appeared as hypercholesterolemia. The increase of cholester the blood depended on work experience.

L. A. Zaritskaya and D. P. Kachalay (1964), in determining arterial pressure in workers in the spinning-weaving industry, found arterial hypotonia in 35% of 107 examiness, asymmetry of arterial blood pressure (systolic and diastolic) in 27.8%, and arterial hypertonia in 13.9%. Arterial hypotonia often occurs without disturbing the organ of hearing, and when its function is damaged autonomic-vascular changes were less pronounced. Asymmetry of skin temperature of the hemitype was noted in these workers (15.2%) as well as the distal type (12.1%), an inadequate reaction to heat and cold stimuli and inertia of the vascular reactions. /235

These vascular disturbances are distinguished by their phase character and do not always coincide with changes of the auditory function.

N. T. Svistunov observed increased blood pressure in electrical machine testers 3 times more often and decreased pressure 2 1/2 times more often than that of the control group. A hypotensive condition is primarily observed in young workers with little work experience.

Often maximum arterial pressure, normal before work, had increased to 165 mm Hg or more by the end of the day. Maximum and mean arterial pressure often increased, cheifly in those with initial high pressure.

N. T. Svistunov (1968) observed a hypotensive condition in newer electric machine testers and a hypertensive state in the more experienced workers. At the same time, he found heightened arterial pressure and vascular tone.

L. Ye. Milkov (1963), as well as N. N. Shatalov et al., found a varying direction of the cardio-vascular reaction in workers in noisy occupations (intensity of noise 114-129 dB of medium and high frequency).

G. Z. Dumkina (1965) examined the condition of the cardio-vascular system in pistol shooters and submachine gunners, taking into account anamnestic data to exclude those who had a past history of hypertonic disease. Her studies of the state of the cardio-vascular system, as those of the authors cited above,

implies that noise leads to vascular dysfunction, changes in blood pressure, disturbed rhythm of cardiac activity (bradycardia, sinus arhythmia).

N. N. Pakrovskiy (1967) studied the state of the cardio-vascular system in machine construction factory workers. In a large number of the people they examined (1069 men), they noted complaints, on the basis of which they could assume the presence of functional disturbances of the cardio-vascular system — shooting and aching pains around the heart, and palpitations. The frequency of complaints increases with age and appear in the greater percentage of cases of workers subjected to the effect of impulse noise (90-95 dB). Systolic pressure was practically the same in the workers (difference in statistical analysis was insignificant).

In examinees of all age groups, deviations in blood pressure were most often encountered on the side of decrease (exception — aged 41 or more) than increase.

An analysis of deviations in blood pressure from normal, in relation to years of work experience in noise conditions, showed that they do not differ from the results of analyzing those with relation to age. The material obtained by N. N. Pokrovskiy shows that industrial noise can lead to the development of a hypotonic or hypertonic condition. The degree of fluctuations of systolic pressure under the effect of noise increases in persons with normal blood pressure, and in those inclined toward hypertension or hypotension, under the effect of noise the variation of systolic pressure is higher than in those with normal tone. /236

B. A. Krivoglaz et al., (1966), studying the health of workers in the spinning-weaving industry, subjected to the effect of high- and medium-frequency noise, exceeding the permissible safe levels by 4-24 dB, often found arterial hypotonia.

A. A. Andryukin (1961a, b) analyzed the arterial pressure of 1232 workers in tool, separator, automatic machine and ball shops of a ball bearing factory. They established that during the effect of a constant noise with an intensity above 93 dB and a frequency over 3000 Hz, hypertonic disease is encountered more often than among workers of other factories in the city of Moscow. In shops with more intense and higher frequency noise, this disease is seen more often than in less noisy shops. The number of "hyperreactors" among the workers of noisy shops is greater than among those working in other Moscow industries. Work experience in conditions of intense noise is very important in the development of hypertonic disease: the

longer the time, the higher the disease rate.

V. I. Skok (1964) measured arterial pressure throughout the working day in nailing shop workers (level of noise was 95-105 dB). His research showed that arterial pressure in some workers increases during work, but in others, on the other hand, it decreases. As age increases, the number of workers with heightened arterial pressure by the end of the shift increases. The dynamics of changes in arterial pressure in different shifts is not the same for different ages. In workers aged 30-39, there were slight changes during all three shifts. In the other age groups, changes were most often found in the morning shift. In comparing arterial pressure during work with normal daily variations, either complete or partial perversion of the daily curve is noted, primarily in the night shift.

A. P. Rusinova (1963 and 1968) indicates the instability of arterial pressure under the effect of noise. According to the data of L. Ya. Basamygina (1963), noise causes a reduction in 30.5% of cases and an increase of arterial pressure /237 in 15.2%. With the development of the so-called noise disease, increased arterial pressure was noted in 47%, decrease in 23.6%.

Usually no parallelism between changes in individual indices of arterial pressure was observed. A. M. Volkov (1958) found primarily an increase in the maximum index. A. P. Rusinova (1963), besides change in maximum and minimum indices, found an increase in mean dynamic pressure, as well. A. I. Vozhzhova, and I. A. Sapov (1960) in functional testing of the cardio-vascular system, conducted after the effect of noise, found an increase in pulse pressure basically due to the increased maximum index.

According to the observations of N. N. Shatalov, for those systematically working under conditions of intense noise, the most characteristic feature is the increased lability of pulse rate and arterial pressure.

A study of pulses in workers in "noisy" occupations showed that during a brief time its frequency can change widely (up to 20 or more beats per minute). At rest, a tendency is most often noted toward bradycardia; in the first hours of the working shift the pulse increases in frequency, and by the end is again reduced.

N. N. Pokrovskiy, determining the pulse rate in workers with blood pressure disturbances, found significantly more changes than in workers with normal blood pressure. In workers with increased blood pressure, even working under conditions with noise at 80-85 dB, the pulse increased 15.5% in frequency during the shift, while with normal pressure, it increased only 6.9%, and in those with low pressure — 11.5%. In those who work under intense noise (90-95 dB), it was increased a greater number of beats than under the effect of less intense noise (80-85 dB).

The effect of noise on the condition of the cardio-vascular system in spinners (medium-frequency noise with an intensity of 100 dB) ai knitters (low-frequency noise with an intensity of 90 dB and, more often, 80 dB) is seen in a hypotensive reaction (systolic and diastolic hypotonia) and, in increased pressure (systolic and diastolic hypertonia). Consequently, the effect of noise of any kind and of sufficient intensity leads to a change in the functional condition of the cardio-vascular system. Only its expression can be different, depending on the parameters and nature of the noise, its time of action (work experience), age of the workers, and the initial condition of the organism.

The electrocardiograms of workers in many noisy shops show a tendency toward both shortening (especially at the inhalation level), and lengthening of R-R, increased time of electric systole of the heart and systolic index, lengthening of the P-Q interval, displacement of the S-T segment above or below the isoelectric line. Besides the enumerated characteristics, V. A. Krivoglaz, A. A. Model' et al. also noted in spinning-weaving industry workers, although infrequently, deformation of the T wave, reduced voltage of the EKG deflections, and increased length of systole (QRST). These data, in combination with the characteristic physical symptoms (slight increase in the dimensions of cardiac dullness, muffling of heart tones, functional systolic noise in the apex), enabled the authors to assume the presence in these workers of miocardial dystrophy, often combined with arterial hypotonia. /238

N. N. Shatalov, A. O. Saytanov, and K. V. Glotova (1962), examining workers subjected to the effect of intense wide-band noise, dominated by high frequencies, often found changes in the electrocardiograms, in spite of the lack of clinical data indicating organic disease of the cardio-vascular system. They most often noted sinus bradycardia and bradyarthythmia, as well as a tendency toward slowing

down of intraventricular conductance was encountered more often. It was, however, less pronounced.

Electrocardiographic studies, which they conducted during the working day, revealed a tendency toward slowing down of rhythm by the end of the shift, and in some cases toward a decrease of the T wave, developing in parallel with deteriorating ballistocardiographic indices.

Phase analysis of the mechanical system of the ventricles, conducted by parallel tracing of phonocardiograms and electrocardiograms, showed that the contracting function of the myocardium in most examinees was not disturbed. A tendency toward lengthening mechanical systole was noted only in isolated individuals with pronounced sinus bradycardia.

Shifts found in electrocardiographic studies are regarded as the expression of neuro-reflex regulation disturbances, as functional disturbances in the nervous system were also found in the examined workers. This frequency increased in proportion to the increased intensity of the noise and the time of working under its action.

For a more complete evaluation of the functional state of the heart muscles themselves and the entire circulatory apparatus under the effect of noise, N. N. Shatalov determined the minute volume of circulation. These data show that the stroke volume of the heart and the minute volume of circulation are often altered /239 in workers under the conditions of noise. Comparing indices of minute volume of circulation with stroke volume of the heart and the frequency of heart contractions, it can be noted that a change in the minute volume of circulation was more often caused by a change in the frequency of heart contractions, less frequently — due to stroke volume.

Some authors found damage to coronary and cerebral circulation during the effect of noise.

Koerrep (1955) attributed great importance to the systematic effect of noise in the development of stenocardia in workers in "noisy" occupations. In his opinion, by causing functional cardio-vascular distrubances, this leads to the development of coronary spasms.

According to the data of V. Ye. Lyubomudrov, B. N. Onopko, and L. Ya. Basamygina (1968), noise in a number of cases causes coronary insufficiency with symptoms of stenocardia, and sometimes myocardial infarction as well.

Significant vascular disturbances of the central nervous system in response to the effect of a sound stimulus are indicated by G. L. Tokhadze (1956), L. V. Krushinskiy, and L. N. Molodkina (1950).

According to the data of N. N. Shatalov, moderate constriction of the arteries in the bottom of the eye are often encountered in those working under intense noise, sometimes combined with dilation of veins.

N. N. Shatalov (1966) on the basis of the distribution rate of a pulse wave and the determination of the elastic modulus of vascular walls showed that under the effect of intense wide-band noise, in whose spectrum high frequencies predominated, increased tone of arterial vessels is noted of both the elastic and muscular type. However, the degree of its increase is more pronounced for muscular type vessels.

A. I. Vozhzhova, and I. A. Sapov (1960), examining machine operators, working in conditions of high-frequency noise with an intensity of 124 dB, found constriction of blood vessels by capillaroscopy. At the same time, skin temperature in the area of the hands and feet decreased by 1.5 - 5.5° C.

L. Ye. Milkov (1963) also often discovered spasm or inclination toward spasm of the capillaries of the underlying bed in persons subjected to the systematic effect of noise with a level of 100 dB. Much less often, normal capillaries are encountered or spastic-atonia and their atonic condition. The spastic state of the capillaries was also found in persons who worked briefly under conditions of noise, which led the author to assume early changes in the capillary channel. At the same time, in these same workers, L. Ye. Milkov conducted a study of tissue circulation in the hands with the help of radioactive sodium (Na^{24}), which showed /240
that tissue circulation there was reduced primarily in the presence of capillary spasms.

The plethysmographic data from persons subjected to the effect of noise is interesting (N. N. Kravkov, 1958).

Recently a great deal of attention has been given to studying the effect of pulse noise.

Ye. Ts. Andreyeva-Galanina, and G. A. Suvorov (1968) point out that biological effect of pulse noise differs significantly from stable. Therefore, there is a basis for assuming that its effect on the cardio-vascular system will also differ in comparison with stable noise.

Of the attendent factors of industrial noise, which in combination with noise have an especially unfavorable effect on the cardio-vascular system, we must note neuro-emotional tension. According to the data of Ye. Ts. Andreyeva-Galanina, G. A. Suvorov, and A. V. Kadyskin (1968), as well as the observations of N. N. Shatalov, among people whose work is connected with the effect of noise and nervous and emotional tension, hypertonic disease is encountered more often than in those where this is absent.

On the basis of these clinical observations and experimental research, it is safe to say that changes in the cardio-vascular system are very typical of the effect of noise, and their clinical pattern indicates neurocirculatory dysfunction.

Very important are questions concerning the nature and expression of hemodynamic disorders, caused by the effect of noise in connection with its intensity and spectral composition, the presence of attendent factors of the industrial medium, the state of hearing, as well as the effect of functional disturbances discovered in hemodynamics on the frequency of cardio-vascular diseases in persons in "noisy" occupations.

A. P. Rusinova, and L. P. Rodionova (1968), on the basis of eight years of observing workers subjected to the effect of stable medium- and high-frequency noise, concluded that the functional damage to the cardio-vascular system, which originally develops under the effect of noise, in time helps develop hypertonic disease and coronary damages.

These data indicate that intense noise is one of those unfavorable industrial factors which cause a number of functional disorders in the cardio-vascular system of the neurocirculatory dysfunction type. Therefore, there is every basis for stating that neurocirculatory dysfunction in certain instances can be considered /241

as one of the syndromes inherent in the effect of noise.

Hemodynamic disorders during the effect of noise often precede the development of permanent changes in the acoustic analysor. Disorders of the neuro-reflector regulatory system of circulation play an important role in cardio-vascular damage. Evidently, the functional disturbances which originally appear in the regulation of hemodynamics under the effect of noise can in time also lead to permanent changes in vascular tone. This can most likely explain the frequency of hypertensive conditions in persons working under intense noise, especially when it is combined with nervous and emotional tension.

Differential diagnostics of neurocirculatory dysfunction, due to the effect of noise, often causes greater difficulties, especially when signs of occupational cochlear neuritis are absent. In making a diagnosis, it is necessary to exclude other etiological factors which accompany the development of neurocirculatory dysfunction (mental and emotional aspects, organic diseases of the nervous and cardio-vascular system, etc.). In each individual case, it is also necessary to consider specific working conditions, the job experience working in noise conditions, the state of health before working in noise, the development time of neurocirculatory dysfunction, the presence and nature of changes in the nervous system and hearing.

As neurocirculatory dysfunction under the effect of noise is primaily due to functional disturbances in higher nervous activity and autonomic centers, therapeutic measures in such cases must be directed toward regulating the nervous system and normalizing reflex reactions of the cardio-vascular system.

Functional state of digestion. Workers in "noisy" occupations often complain of stomach dysfunction. Of special interest, therefore, is the research of B. A. Krivoglaz, and A. A. Model'. Studying the secretory function of the stomach, they most often found weakening, and less frequently — intensification. In one third of those examined, a reduction in the acidity of stomach contents was found; much less often, an increase was noted. Fractional study of stomach contents showed a depression of hourly rate of secretion in one third of those examined; less often it increased.

Paradoxical reactions were observed to the introduction of various stimuli.

Thus, with Boas-Ewald's test meal, the acidity of the stomach contents was normal or increased. After the administration of a stronger stimulus (alcohol) to these same people, the acidity decreased in a number of cases. Curves of gastric secretion show its pathological types; excitable, asthenic, inert and inhibited. /242

The evacuatory function of the stomach was disturbed in more than half of those examined, primarily slowed down, less often — accelerated.

In roentgenoscopy, the authors most often noted hypotonia, less o n increased tone of the stomach with intensification of peristalsis, with no signs of organic disease, which gives a basis for considering these disturbances as functional.

In studying the functional state of the stomach in workers, the same regularities are observed which were noted in studying the functional state of the central nervous system and its autonomic section, as well as the cardio-vascular system, namely: increase in disturbances with job experience and parameters of noise and lack of dependence on the state of the acoustic analysor. Functional disturbances in stomach activity were also encountered with a normal acoustic function, as well as with slight pathology of the nervous system. The authors consider stomach function disorders and disturbance of the functional state of the cardio-vascular system as an early sign of the effect of noise. Evidently, changes in the functional state of the central nervous system should also be added to this. The works of the Clinical Section of the Liev Institute of Industrial Hygiene and Occupational Diseases have significantly broadened our knowledge of noise sickness, filling in existing gaps in this complex and urgent problem.

Noise can also lead to the development of a non-occupational sick rate. Thus, in weavers, whose working day is spent in conditions of noise with medium- and high-frequency spectrum with an intensity of 103-107 dB, the sick rate in relation to that of all workers is 134% in cases and 111.4% in days (L. N. Shkarinov, (1964-1966).

Comparing changes in physiological functions in experimental animals under the effect of noise with clinical syndromes of noise sickness, we see their identical direction. The latter significantly broaden our ideas of the effect of noise on the organism. Morphological, histochemical and electroencephalographic studies using several neuropharmacological drugs and other studies reveal the participation

of individual structures of the central nervous system in the mechanism of noise pathology development.

We have discussed in detail the symptoms of the nonspecific effect of noise. But the pattern of its general biological effect would not be complete enough if we excluded the nature and time of development of hearing damage in workers in noisy industries. Perhaps not as many works deal with any of the symptoms and syndromes of noise sickness as the functional and pathological state of the organ of hearing, which is completely explicable, considering the importance of this organ in human life. /243

Noise has attracted the attention of doctors for nearly a hundred years. However, the majority were restricted to studying the state of hearing and did not attempt to establish a connection between the general reaction of the organism to noise and those changes which occur in this analysor. There are only isolated observations on disturbances in certain functions. Only in the last 10 years have works appeared advocating the necessity of studying the condition of the organism as a whole and comparing changes observed in certain of its functions with the condition of the analysor. The works of N. N. Pokrovskiy, as well as B. A. Krivoglaz and A. A. Iodel' et al., in this direction, fill in the shortcomings of many works.

Changes in the organ of hearing. The most valuable method of diagnosing occupational deafness is tonal audiometry, which can evaluate the perception of individual tones in a wide range. Objective audiometry has the advantage over this method of excluding voice control. It is based on the reflex reaction, developing in response to auditory stimulation. Unconditioned and conditioned reactions (flickering, galvanodermal reactions, etc.) are used. In addition to tonal audiometry, vocal audiometry is also used.

Three forms of damage to the organ of hearing of occupational etiology are differentiated: 1) damage to the inner ear, developing gradually and progressing with job experience; it is encountered relatively infrequently; 2) combined damage of the middle and inner ear — the most common form of hearing damage; 3) chronic catarrh of the inner ear with symptoms of inner ear irritation, attacks of dizziness of the Meniere's disease type.

To recognize deafness, S. Z. Romm suggests first of all finding out if the

sound-conducting or the sound-perceiving section of the acoustic analysor is damaged and localizing the damage — hair cells, ganglion, stem of the auditory nerve. These questions can only be answered by the occupational pathologist-otorhinolaryngologist.

Criteria are needed to establish occupational deafness by the tonal audiometry method. The most indicative criterion is the reduced perception of 4096 Hz (4000 Hz). Ya. S. Temkin (1957) assumes that isolated reduction of this frequency is encountered rarely and only in the presence of complete deafness. He studied the condition of the hearing organ in two groups of workers — weavers and boilermakers working with pneumatic tools. In the first group, 86.7% reduced perception of a 4096 Hz tone was observed, 2048 Hz — 85.7%, 1024 Hz — 56%. Reduced perception of a 4096 Hz tone is thus encountered as often as that of 2048 Hz. The same observations were made in the group of boilermakers. The majority of researchers are of the opinion that a significant reduction of perception of a frequency of 4096 Hz and higher (sometimes up to 8000 Hz) is typical of occupational deafness; later the threshold of auditory sensitivity to frequency 2048 Hz changes as well. Usually an audiogram with almost the same trough at both these frequencies is characteristic of pronounced deafness. /244

In evaluating damage to the auditory function, it is also important to know the relation between the original (constant) threshold of audibility and its temporary displacement. They converge with experience working in a noisy occupation. For example, if the difference between the constant threshold and the temporary was 13 dB with under 4 years on the job, it was only 4 dB in the 5-9 year stage.

Perhaps not as many works deal with any of the symptoms and syndromes of noise sickness as with the functional and pathological state of the organ of hearing, which is completely explicable, considering the importance of this organ to human life.

It is not possible to present all the data on this subject in this monograph. In the Soviet Union, examples of the development of deafness in workers in various specialties, the characteristics and time of development and other aspects of damage to the ear have been studied by the major scientists specializing in otolaryngology in this country — V. G. Yermolayev (1941), L. A. Kozlov (1949), Ya. S. Temkin (1957), G. S. Trambitskiy, S. Z. Romm, G. L. Navyazhskiy,

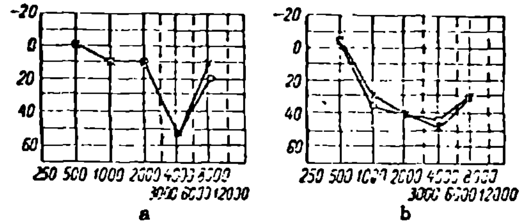


Figure 63. Curves of hearing loss in weavers (after Zittler).
a — aged 20-32 years; b — aged 33-46 years.
Vertically — reduction of hearing, dB;
Horizontally — frequency, Hz.

V. F. Udrits and others.

The development of deafness can be abetted by infectious diseases: scarlatina, measles, diptheria, erythroblastosis, leukemia, nephritis, menengitis, tuberculosis, herpes zoster, mumps, toxoplasmosis and several drugs (quinine, salycilates, arsenic derivatives, etc.). Developing first without significant hearing symptoms, it is often accompanied by noise in the ears, and dizzyness and can later be combined with inner ear damage. Many toxic substances and irritating media can cause the pathological process. In studying the effect of industrial noise on the organ of hearing, it is thus necessary to have exhaustive anamnestic data, /245 to know past diseases as well as the factors accompanying the noise.

Without doubt there is some adaptability to noise, but it does not insure against the development of the pathological process, but only puts off the time when it appears; this has been conclusively indicated by the data A. G. Rakhmilevich (1964).

The criterion of deafness is the threshold of audibility. A. G. Rakhmilevich suggested a scheme for determining the degree of deafness: 1st degree corresponds to 35 dB reduction of perception of a 4096 Hz tone, with simultaneous 10 dB reduction of hearing in the low and medium frequencies; 2nd stage — 40-45 dB reduction of perception of a 4096 Hz tone and 15 dB reduction in low and medium frequencies; 3rd degree — 50 dB reduction of a 4096 Hz tone and 20 dB or more in the lower and medium frequencies.

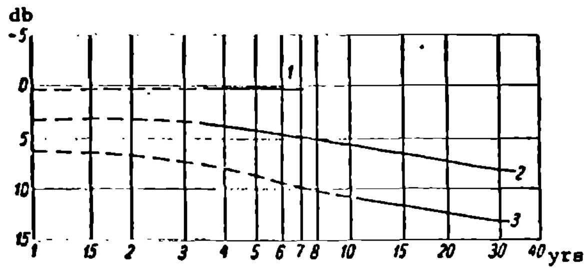


Figure 64. Change in auditory function in relation to time on job and intensity of noise (1 — 80 dB; 2 — 88 dB; 3 — 95 dB).
Vertically — hearing loss (in dB) at 1000 Hz;
Horizontally — time (1.5, 2, 3 . . . .).

Progressive deafness is observed with increased stages of work. In the percentage indices, for example, under 5 years, the number of cases of deafness from noise and vibration was 15.4 ± 5.8 (with the effect of noise alone 6.2 ± 6.0) and between 6-10 years — 59.4 ± 8.1 (noise alone — 53 ± 12.9), and for over 10 years — 96.5 ± 3.5 (noise alone — 59.4 ± 8.1). Total percentage of cases of deafness in boilermakers subjected to vibration and noise and to noise alone was 61.0 ± 4.5 for the first group of workers, and 36.9 ± 7.1 for the second group. The difference in indices was reliable ($P < 0.05$).

The first degree of deafness is most often noted with under 10 years of work experience; later, 2nd and 3rd degrees cannot be clearly differentiated in time.

Figure 63, a and b gives the curves of the threshold of audibility in weavers aged 20-46 years. We can see that the length of time on the job is more important than age. Figure 63, a, presents the thresholds for those aged 20-32 years, and Figure 63,b — for 33-46 years. The curves are extremely typical for judging the /246 progressive reduction with work experience of auditory sensitivity, regardless of age. In proportion to increased work experience, the threshold of auditory sensitivity is significantly reduced in the area of perception of 1000-2000 Hz (35-40 dB), while at a younger (relatively) age and less time, it is only reduced 10 dB. Figure 64 shows the curves of hearing loss in the perception of a 1000 Hz tone with intensity of 80, 88, and 95 dB in relation to job experience and therefore,

age. From this, one can judge how differently the threshold of auditory sensitivity changes with job experience. At less than 5 years, the threshold of perceiving a 1000 Hz tone increases 3-7 dB at an intensity of 88-95 dB; at 20 years experience, 7-13 dB. If another higher frequency were taken as a criterion,undoubtedly the results would be still more striking. Without question, constitutional aspects play a role. In some people, the auditory function is very quickly disturbed, in others, even in conditions of comparatively intense noise, it develops slowly. Even with high-frequency noise with a level of intensity as high as 100 dB, deafness takes years, less frequently, decades.

Dissimilar sensitivity of the organ of hearing to noise is also found in workers. Ya. S. Temkin found a different reduction in workers of the same occupation and an identical stage of auditory sensitivity, in some no changes were noted, and in still others, perception of low frequencies deteriorated. He did not detect selective reduction of perception of 4096 Hz, although changes in the threshold to /247
perception of this frequency were greater. These studies rather refute the assertion of Fowler about the preferential exclusion of perception of a 4096 Hz tone. Békésy (1947) attributed the isolated reduced perception of this frequency to the tension which is experienced by the part of the basilar membrane perceiving 4096 Hz during noise stimulation. In his opinion, there is a juncture of an perilymph vortex during the effect of intense noise in this particular part, verified on models. However, the point of view of Ya. S. Temkin is more correct.

The degree of change in auditory sensitivity is also affected by the state of the central nervous system: sensitivity to noise or sounds can be aggravated. A. I. Bronshteyn (1946) observed not a decrease, but sensitization of hearing after a sound stimulus.

Damage to the acoustic analysor depends on the intensity of the noise. At low frequencies of stable noise, it appears with an intensity of 100 dB (according to some authors, 110 dB); at medium frequencies — at 85-96 dB; and at higher frequencies — 75 dB. According to literature data, high-frequency noise of 70-75 dB is tolerated for a long time without injury to the auditory function, but V. G. Yermolayev feels that the fatiguing effect from this noise is felt even at 60 dB.

With high-frequency noise, the threshold of auditory sensitivity is reduced

40-60 dB at 100-120 dB, with a maximum change of sensitivity to a 4000 Hz tone.

Medium-frequency noise causes fewer changes in the 4000-6000 Hz range than high-frequency noise. It is interesting to note that the research conducted by S. V. Alekseyev on the effect on auditory sensitivity to medium-frequency noise of various intensity with maximum sound energy at 300, 500 and 700 Hz, established that they affect the perception of vocal frequencies (500, 1000 and 2000 Hz). Under the effect of noise with maximum sound energy at 500 Hz, auditory sensitivity is reduced 10-14 dB at frequencies of 500-2000 Hz. The threshold is changed more by a sound stimulus with a tone of 700 Hz than 500 Hz, and even more with 300 Hz.

Numerous observations indicate that at the same levels of noise intensity and sound, their effect is more pronounced during high-frequencies.

High-frequency sounds with an intensity of 110-113 dB lead to a significant loss of hearing sensitivity; they can be restored quickly at first, then it is slower. Complete restoration of 60 dB hearing loss occurs in several days. /248
Recovery of audibility after fatigue with a 1000 Hz tone, with an intensity of 90 and 100 dB, is uneven. At first, the threshold of hearing sensitivity is reduced, then it again increases, after which it slowly begin to fall. Only at a level of sound pressure of 20 dB does this phenomenon not occur (Hirsch, 1962). The opinion has been advanced that the discontinuity is due to the superposition of two processes: physiological (nerve-stimulating) and chemical.

Audiometric studies, made by many authors, convince us that in experimental research and in examination of workers the most pronounced and earliest to develop are changes in the threshold at 4000 Hz and at 2000 Hz, and often also at 6000 Hz. Reduction at other frequencies is much slower.

S. V. Alekseyev and G. A. Suvorov, studying noise with even spectral density throughout the frequency range (30-12000 Hz — white noise), found no pronounced changes in the thresholds of hearing sensitivity with an intensity of 70 dB, whereas with 80 and 90 dB intensity at 3000-6000 Hz they were considerably decreased. In particular, it was reduced 20 dB with an intensity of 90 dB. These data indicate the undoubted importance of noise intensity.

The development of deafness also depends on the nature of the noise. It

develops more quickly if the stimulus is pulse noise, if there are fluctuations of the tones, especially high frequency, and noises with a changing level of loudness.

Dieroff (1961, 1962) in audiometric examinations of 1850 workers in noisy industries, found, with a simultaneous analysis of noise, an interesting phenomenon-in a steel rolling mill, where the predominant level of sound pressure was 105 dB, and high frequencies reached 10,000 Hz, the workers had less hearing loss than those who worked in the press shop with a level of noise about 90 dB, with a predominance of low frequencies. Attention was given to the fact that in the latter case there was a greater reduction of sensitivity to a 4000 Hz frequency. The author sees the reason for this difference in the nature of the noise. In the press shop, it was pulse noise. Analogous phenomena are observed in stamping workers and several other noisy occupations.

The effect of impulse noise on the organ of hearing was, until recently, poorly understood. O. P. Shepelin (1959) found that under industrial conditions, pulse noise causes more pronounced shifts in the human organism than medium-frequency and even high-frequency noise. In experimental conditions, G. A. Suvorov found that in addition to the spectral composition and the intensity, the parameters /249 of pulse noise, such as pulse recurrence rate per unit of time and rhythm, are also very important. As has been shown, at a frequency of 200-500 ppm, the effect of pulse noise does not essentially differ from stable noise similar in energy and loudness, while infrequent (30 ppm) and frequent (1000 ppm) cause important shifts in the human organism. The rhythm of the stimuli is also important. Pulses with no definite rhythm cause more pronounced shifts than those with a definite rhythm. The most pronounced effect is observed with infrequent stimuli. At this time, large shifts are also observed in the central nervous system as well. Of special interest are the data of Ya. A. Al'tman, who found that infrequent sound stimuli cause a different kind of reaction than frequent stimuli. The most serious changes were found in the central links of the acoustic ayalysor; he studied the conductive and cortical centers.

The pathogenesis of the development of deafness must be analyzed at the level of the peripheral and central sections of the acoustic analysor. In analyzing it, we must clarify the deep processes which occur in cellular formations and the changes in biochemical processes on the basis of histochemical research.

Morphological methods have long been used to ascertain the characteristics of the state of the peripheral section of the acoustic analysor, particularly its organ of Corti and the spiral ganglion. The central link was not studied; only in 1964 did the first experimental work of G. N. Krivitska appear, shedding some light on processes which occur in the brain during the effect of noise with an intensity from 80 to 130 dB and, evidently, of high frequency. With this research, L. N. Krivitskaya, as well as Ya. A. Vinnikov and A. K. Titova, obtained new data on the development of occupational diseases of the acoustic analysor. In the group of works dealing with the pathogenesis of the development of fatigue and deafness, we must also note the work of V. F. Anichin.

Many different hypotheses have been advanced in relation to the pathogenesis of fatigue and deafness, more valid, probably, for judging the state of fatigue only.

It has been suggested that the prolonged effect of noises will lead to pathological processes in the cochlea, which can be explained also as the result of overstrain of subcortical acoustic centers regulating tropism of the inner ear (G. A. Komendantov, 1933; L. G. Komendantov, 1937; M . P. Mogil'nitskiy, 1936; S. A. Vinnik, 1940). G. L. Navyazhskiy saw that the development of fatigue is based on overstrain of inhibitory processes, exhaustion of the sound perceiving apparatus and damage to receptor cells. Some feel that damages in /250 the cochlea are due not only to the direct effect of sound, but also that moderated through the cerebral cortex, regulating the tropism of the peripheral section of the acoustic analysor.

Haberman (1890) was one of the first to detect changes in nerve endings of the basic spiral of the cochlea in a 75 year old man, who had worked many years under conditions of noise (20 years). The organ of Corti and the basilar membrane in this case were atrophied. Changes were also noted in the part of the organ of Corti adjacent to the round window, nerve fibers were also atrophied. Irrefutable data was obtained by Zange (1911) in a young boiler maker who died at the age of 29, after having worked with pneumatic tools at his job for 10 years. Deafness had progressed for 6 years. After death, the same phenomena were found which had been described by Habermann. However, a thorough concept of the state of the second-perceiving apparatus was first obtained by N. F. Popov (1929a), who noted morphological changes in the basilar spiral of the cochlea of white mice.

Changes were observed not only in the zone perceiving certain tones of the stimulus, but also on both sides of it. The degree of change depended on the level of sound pressure and the length of its action. It is assumed that the ganglionic cells can remain intact even when the peripheral receptors are damaged. Marx, Hoessli (1913) and Rohr (1912) suggested that ganglionic cells can remain intact if the peripheral receptors are completely destroyed. In monkeys after the effect of a 5 Hz frequency daily for 45 days beginning from the middle of the first spiral of the cochlea, a number of deviations from normal was found, and part of the hair cells was absent. In their place were homogenic non-nucleated masses. There were no changes in the nerve fibers or ganglionic cells. During the effect of 4 Hz sounds of a tuning fork, a change was noted in the shape of hair and Dieters cells, and a change in the tension of Reissner's membrane.

Wittmaack (1929), experimenting with intense sound at 2048 Hz, found complete destruction of the organ of Corti and nerve fibers. He also found that under the influence of noise, changes are localized in various sections of the cochlear spirals and that this is connected with the frequency of the sound stimulus. The higher the sound, the closer to the bottom of the cochlear spiral were the sounds localized, and vice versa. Later, the same localization was observed by Ya. A. Vinnikov and L. K. Titova (1957, 1958, 1961).

S. A. Vinnik and V. G. Yermolayev found morphological changes encompassing neurons of the spiral ganglion, — the definition of their shapes disappeared, chromatolysis, vacuolization of protoplasm and decay of nuclei were noted. Changes /251 also developed along the nerve fibers, uneven goblet-shaped swelling formed along the fibers, formation of constrictions and fiber decay are also possible. In short, degenerative-dystrophic processes were taking place.

After prolonged noise, changes in the neurons of the spiral ganglion are expressed in wrinkling, deformation and more intense staining of nerve cell nuclei. In the opinion of many researchers, changes appear later in nerve cells than in the connective tissue of the peripheral section of the acoustic analysor, However, this observation requires further study.

It is perfectly clear from the standpoint of current views on the pathogenesis of the development of particular diseases that morphological research does not give a complete picture. Most interesting are cytochemical data.

In cytochemical studies of cochlear ganglia in guinea pigs, various cytochemical changes were detected after acoustic stimuli of various frequency. Stimulation with a sound of 8000 Hz and 80 dB led to a reduction in the amount of protein substances in the brain and ganglionic cells after the test. It is interesting that parallel with this decrease, a tendency toward restoration was observed. Reduction of the protein content continues through the second week after the test; only in the third week did restoration begin. Observations of the above authors indicate that intense sound trauma, even comparatively brief, with sufficiently intense high-frequency sound, leads to persistent changes in exchange processes in ganglionic cells. They also conducted studies with the effect of a high-powered stimulus, in the form of 12 pistol shots for 6 days, which can be considered as a stress acting 2 times a day. Such a stimulus can lead to sound trauma. Therefore, it is no wonder that after its effect the authors found more persistent and more significant changes than in the first series of tests. Changes were also observed 8 weeks after the trauma, although signs of recovery had been noted already.

L. I. Maksimov also described tests with a pistol specially constructed for driving in dowels. A damped wave lasting 5 o was formed, composed in turn of two waves. The pressure of the first was 163-168 dB, the second — 158-162 dB. Following them, sound vibrations of 885-4650 Hz developed with a pressure level of 140 dB. After 4-5 shots, the threshold of auditory sensitivity was raised 10-20 dB at frequencies of 4096-1048 Hz, and recovery was made in 15 seconds and 1.5 minutes. After longer action of the shock waves, the threshold was raised /252
14-16 dB, recovery in 10-15 minutes.

Many authors point out that these changes can be considered not as pathological, but as physiological. The protein forming system of the nerve cell has a large capacity and is able to maintain equilibrium even under conditions of very strong consumption. However, the inference that biochemical processes have a physiological basis is valid for certain parameters and time of stimulus. Later, without doubt, they assume a persistent character, they emerge, although slow to develop, as dystrophic processes.

T. N. Zelikina and V. Ye. Shungskaya (1958) studied the effect of a low tone of 200 Hz and a high tone of 4000 Hz with an intensity of 120 dB, affecting guinea pigs for 3 hours. They detected distinct changes in nerve cells of the

cochlea and the area vestibularis of the medulla oblongata, consisting of reduced tigroid, change in the forms of nerve cell nuclei, and the presence of fissionable nerve cells; the most pronounced were changes in nerve cells of the area vestibularis. They found no changes in the nerve cells of the cortical end of the acoustic analysor. An idea of the development of processes was obtained during extensive histochemical research. In this direction, we must note the works of Ya. A. Vinnikov, L. K. Titova and V. F. Anichin.

The material obtained by the histochemical method can be completely used to obtain a concept of processes which precede fatigue and the mechanism of the development of deafness.

Industrial hygiene is interested in whether these processes occur equally in the cochlear organ or if there is some difference in them during the effect of noises of varying character and spectral composition. As far as we know, the only work in this direction is that of V. G. Anichin (1965, 1966, 1968). One of them relates to the effect of pulse noises, the second and third to sounds of various frequency, but with the same intensity. Thus, we have available information which will give an idea of the reaction of individual cellular formations of the organ of Corti of the effect of several areas of the spectrum of acoustic vibrations and to one of the little-known forms of sound stimulation — discontinuous noise.

V. F. Anichin conducted histochemical studies of the organ of Corti of guinea pigs after the effect of sounds at 4000 Hz with an intensity of 100 dB for from /253 one half hour to 12 hours. The author found changes in the two lower spirals of the cochlea. Attention was concentrated on the consumption of diffuse karyoplasm RNA, in relation to the time of the stimulus effect. During 0.5-4 hours of the effect, diffuse karyoplasm RNA was significantly consumed, the dimensions of the nuclei of external hair cells increased. A longer (6 hours) noise effect is accompanied by an increase in the concentration of karyoplasm RNA and a reduction in the size of external hair cell nuclei.

With the daily 6-hour action of sounds of these parameters, leading to a fall in auditory function in white rats, the author often found pronounced degenerative-dystrophic processes primarily in the external hair cells. Such changes were not found in the spiral ganglion or nerve fibers of the peripheral

section. There was also a reduction in the activity of acetylcholinesterase and in the concentration of nucleic acid (Figure 65) in the organ of Corti and the upper cochlear spiral (Figure 66).

V. F. Anichin in a daily 6 hour sound stimulus did not note any changes in the spiral ganglion or peripheral nerve fibers.

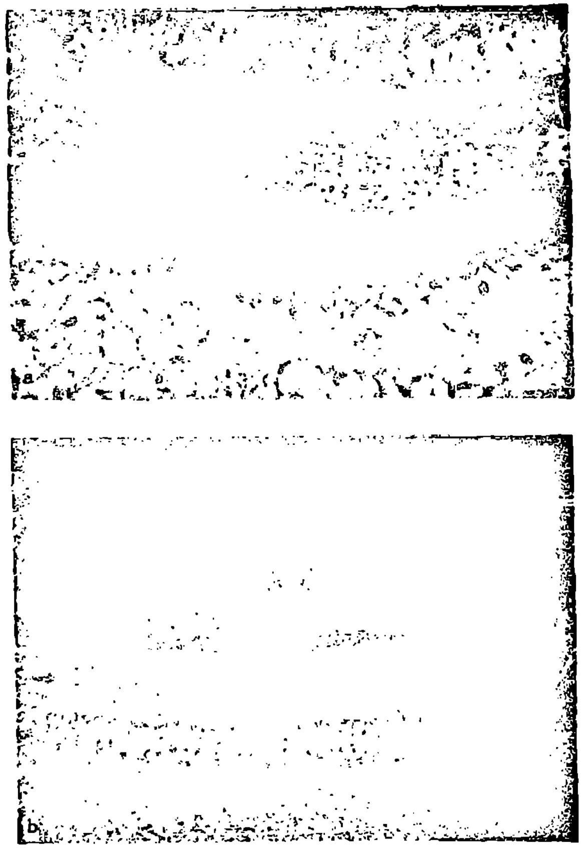
One cannot help but agree with the conclusion of the author that the data he obtained indicate the primary nature of acoustic receptor damage.

A 12-hour effect is accompanied by the above impoverishment of diffuse RNA in karyoplasm and cytoplasm as well as in inner hair cells. The nuclei of external hair cells lose the ability to increase their sizes, while the nuclei of internal cells maintain theirs.

These changes, as a rule, were observed in the lower spirals and partially in the lower-middle spirals of the cochlea (in guinea pigs). Under the effect of an acoustic stimulus with a frequency of 500 Hz (100 dB), these same changes were noted in the upper-middle and upper spirals (apex sections). V. F. Anichin (1965) also studied the influence of discontinuous sound on the organ of hearing of white mice. A stimulus with a recurrence frequency from 30 to 1000 times per minute was supplied. The conditioned reflex to a sound stimulus of 500 and 4000 Hz was taken as a criterion of the effect of noise, along with the histochemical control. Sound trauma continued until complete collapse of the conditioned reflexes.

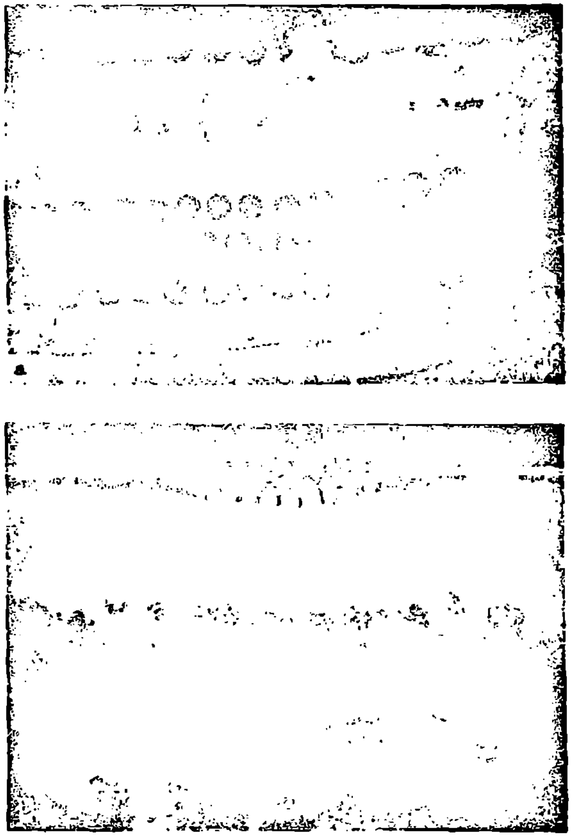
Parallel histochemical studies were also conducted. Serving as a control were the changes which also develop in the membranous labyrinth after the effect of stable noise. Figure 67,a gives the normal structure of the membranous labyrinth of the upper spiral of the cochlea, and Figure 67,b — after a prolonged sound effect (4000 Hz, 100 dB) until complete collapse of the conditioned reflex By these studies, V. F. Anichin verified the already described earlier changes /256
noted by a number of authors. Changes relate primarily to the external hair cells; the initial stages of degeneration are developing.

Under the effect of sounds with 1000 interruptions per minute, changes were most pronounced, and at 30 per minute — they were the same as with 200 interruptions per minute.



/254

Figure 65. Activity of acetylcholinesterase in the organ of Corti (after V. F. Anichin).
a — normally; b — after the effect of noise with a frequency of 4000 Hz and a level of intensity of 100 dB.



/255

Figure 66. Distribution of nucleic acid in the organ of Corti.
a — normally; b — under the effect of a 4000 Hz tone with a level of intensity of 100 dB.

Figure 67. Structure of the membranous labyrinth of the upper spiral of the cochlea (after V. F. Anichin). a — normally; b — after prolonged effect of stable noise with an intensity level of 100 dB.

The studies of V. F. Anichin established that discontinuous noises have a greater effect than stable. During the prolonged action of high-frequency sounds with collapse of the conditioned reflex, degenerative changes are observed in animals, primarily in the external hair cells of the organ of Corti, as well as a reduced nucleic acid content, increased nucleus size, reduced activity and disturbed structure of acetylcholinesterase distribution. /257

Concerning the state of reflexes during the effect of discontinuous sounds with frequent and infrequent interruptions (100 and 30 per minute), the author noted their earlier collapse with discontinuous sounds (200 per minute). This regularity is characteristic (according to the author) of the effect of both

high-frequency (4000 Hz) and medium-freqeuncy sounds (500 Hz).

The classic cytochemical studies, presented in the monograph of Ya. A. Vinnikov and L. K. Titova, give an idea of the localization and distribution of chemically-active substances in the organ of Corti and its receptor elements during sound stimulation of the organ of hearing.

In the section on the cytochemical theory of hearing, data has already been given which characterizes the auditory function from this standpoint.

The authors observed a change in the activity of acetylcholinesterase during the effect of high sounds (1500-7000 Hz, intensity 95 dB). After 15-20 minutes it increases, and after 1-2-4-6 hours — it decreases in structures of the lower cochlear spirals. Low frequencies cause analogous changes in the area of upper cochlear spirals. The authors assume that this phenomenon plays a role in the development of excitation of hair cells and in its transmission in the form of a pulse through synapses to afferent fibers of the spiral ganglion. This mechanism underlies the transmission of a pulse to the hair cells by efferent fibers of Rasmussen's bundle. Ya. A. Vinnikov and L. K. Titova point out that cells of the organ of Corti are not so much mechanoreceptors as mechano-chemoreceptors.

Their observations are interesting that after a one-hour effect, the total amount of glycogen in the organ of Corti does not change, although the excitation process is taking place, while others observed a decrease in the concentration of glycogen in 2-5 hours after the effect of sounds. Changes occur in content of nucleic acids, alkaline and acid phosphatase, and succinic dehydroginase (Ya. A. Vinnikov and L. K. Titova).

Naturally the question arises: is there a sufficiently proven connection between those biochemical processes which occur in the peripheral link of the acoustic analysor and the development of deafness? This question is answered by the conclusive experimental research, conducted by Ya. A. Vinnikov and L. K. Titova; we can see verification also in the data of Vosteen (1956, 1958), who detected a change in the content of the respiratory enzyme after a noise load — namely, its decrease. Great physiological consumption of enzymes disturbs the nourishment of the hair cells, which can aid in the formation of permanent damages. /258

Bugard (1955) observed, in the brain of rabbits subjected to the effect of intense noise, expansion of perivascular sneaths and the perineural channels, which is accompanied by a state of porosity of brain substance. Similar changes were found in the cortex of the frontal, temporal, and parietal areas.

Interesting experiments were conducted studying blood circulation in the human brain by means of rheography by I. B. Yevdokimova, I. K. Razumov and L. N. Shkarinov (1968) during the effect of octave noise bands with levels of intensity of 80 and 90 dB for 1, 2 and 3 hours. In only an hour after the start of the noise effect, the blood volume in vessles was reduced as well as their tone. This appeared especially distinctly after the effect of a 1000 Hz octave band. A 2-hour effect causes a lesser reaction, and there is even a tendency toward normalization and increased blood volume. After three hours of the experiment, there is a slight increase in the blood volume of the vessels of the brain and their increased tone (4-8%). Unfortunately, at the present time we still cannot compare these data with material on the oxidizing processes in the human brain, as the latter have been conducted on animals.

Thus, noise disturbs the blood supply, disturbs the normal course of exchange processes and can lead to morphological changes in the structure of the brain.

The research of G. N. Krivitskaya is interesting. She set herself the task of studying the state of the morphological structures in the brain of animals subjected to a sound stimulus. As a stimulus, the author used a bell with an intensity level from 80-130 dB. The author, unfortunately, does not give the frequency parameter of the stimulus. Evidently, it had a high frequency. The author experimented with two groups of animals, which she selected by reason of their attitude toward noise. In the first group were those animals which did not react to noise with tonic or clonic convulsions, and in the second group those in which reactions were very pronounced.

The author indicates that at the start of the sound stimulus, the first group of rats made movements of "preening", "washing," licking the hair, there was involuntary defecation and urination, and then the animals hid in the corner and remained still. Limpness was noted after the test, fearfulness was seen in /259
some, and then drowsiness; after 23-44 tests their hair became dull. The author

conducted 1-2 tests per day, lasting from 5 to 15 minutes. The stimulus was given from 6 to 44 times.

The second group of rats was subjected to a 5-minute daily effect with currents from 500-1500 Hz, intensity of 80 dB for 3-7 months.

After the effect of six sound stimuli, G. N. Krivitskaya noted slight pathological changes in nerve cells, fibers, glia and vessels. Besides their significant number, they also maintained their structure.

In the area of the cortical section of the acoustic analysor in the 3rd and 4th layers, the author observed predominantly slightly hypochromatic nerve cells, indicating the presence of moderate chromatolysis. Their nucleus was increased in size, nucleoli were hypertrophied. The number of such cells was small, 2-3 per 100. Analogous phenomena are also observed in the cortex of the dermomotor analysor. It also contained hyperchromatic cells, uneven and angular. Varicose dilation is seen in the dendrites. There are changes in myelin fibers in the form of swellings at the cortical ends of the auditory and dermomotor analysors.

In some cells of the medial geniculate body — chromatolysis (moderate); in isolated cells of the lower prominance of the colliculi there was a change in their structure . There were slight changes in the hypothalamic region and in the reticular formation.

A longer sound stimulus (23-27 minutes) was accompanied in the cortex of the auditory analysor and in the lower prominences of the colliculi by an increased number of hypochromatic nerve cells and by the appearance of hyperchromatic cells — in the first — peripheral and segmental chromatolysis and deformation of nuclei; in the lower prominences of the colliculi, diffuse chromatolysis was also observed. The neurons of the auditory nerve nuclei are altered. Changes are seen in the cerebellum, the hypothalamus and reticular formation. Changes develop in the epithelial nuclei of cerebral vessels. Thus, during that period of the sound stimulus a state of parabiosis develops — paranecrosis.

Sound stimuli (up to 44 minutes) cause changes which are more significant in character and scale in all those same areas. Existing damage of neurons in various sections of the brain is accompanied by changes in vascular and glial tissue.

In the walls of vessels, there is thickening of argentophilic fibers, pronounced disturbance of vascular tone (spastic-atonic character), increased penetrability of the vessels.

In animals with a tendency to react to sound stimulation with convulsive /26C paroxysms, G. N. Krivitskaya principally noted the same changes in the structures of the central nervous system as in those in which sound does not cause convulsions. There were, however, certain characteristics. A large number of neurons with a diffuse process of chromatolysis were encountered in hypochromatic cells; the contours of these cells were indistinct, they were changed into ghost cells, in several vacuolation was noted. Some of the cells were reduced in size. After the convulsions, deformation of the nuclear envelope was observed, nerve cells with double nuclei are often encountered. Deformation was noted also in the branches, there was a large number of dendrites with spherical swellings and pericellular edema.

There were significant changes in the vessels. Swelling of endothelial nuclei, dilated opening of vessels their overfilling with blood, plethora of vessels of the soft cerebral membrane , hemorrhage with centers of softening.

After one convulsion, the most changed were the neurons of the dermomotor and auditory analysor, primarily the first. All its links are affected — from the cells of the spinal cord to the cortical end of the analysor.

In animals killed after several tests, numerous hemorrhages were found in the ventricles of the brain, in gray and white matter. Pronounced damages and broader localization were noted in all formations, which was discussed above. Structural changes appear in the cerebellum and reticular formation.

On the basis of his observations, the author concludes that during the effect of a sound stimulus, without stratification of sensitivity, most damage is noted in the cortical section of the acoustic analysor, and, when there are convulsions,in the area of the cortical representative of the dermomotor analysor.

Of undoubted interest are the data of the author on the number of damaged neurons in the cortex and subcortex. They are more numerous in the cortical endings of the analysors than in the subcortical, i.e. in those formations which are

phylogenetically and ontogenetically younger. But the structure of the cortical neuron is more quickly rearranged in reactive change, and during rest it is more quickly restored to normal than in the neurons of subcortical formations.

In animals which are not subject to convulsions, a certain predominant susceptibility of subcortical links of the acoustic analysor is observed in morphological disturbances, whereas in those subject to these convulsions, it is the motor analysor. In the opinion of G. N. Krivitskaya, exhaustion of Nissl bodies, which might be the reason for fatigue, and localization of altered neurons in the hypothalamic areas of the brain are characteristic of increased blood pressure and other autonomic reactions. /261

We cannot help but agree with the opinion of the author that her data make it possible to explain in a new way the pathogenesis of the development perhaps not so much of deafness, as changes in the general condition of the organism, functional disturbance of its organs and systems. We are obliged to G. N. Krivitskaya for these studies: she enabled us to approach in a new way those complaints and objective symptoms and syndromes which are typical of the pathology caused by noise which we have called noise sickness.

A large number of works deal with occupational deafness. The first works appeared in the middle of the 19th century. Lately the number of works dealing with deafness in workers in various occupational groups has been increasing. A large amount of work in revealing the prevalance of deafness and methods for determining it has been done by Ya. S. Temkin, S. Z. Rozen, V. G. Yermolayev, A. G. Rakhmilevich and others.

Table 47 is presented as an illustration of cases of deafness in workers of several shops in which the spectral composition and level of noise are the basic etiological factor in the development of a pathological condition of the acoustic analysor.

Ya. S. Temkin noted deafness in 71.3-90% of motor testers, L. A. Kozlov in riveters and metal cutters (40-61%), A. M. Medovoy — in those working with sheet-beating hammers (45%). Jansen gives a list of occupations such as concrete worker, cement grinder and many others which did not exist in the past. In recent years, data has been obtained on the condition of the organ of hearing in miners,

TABLE 47

DEAFNESS IN SEVERAL OCCUPATIONAL GROUPS
(WITH WORK EXPERIENCE OVER 5 YEARS)

Occupation	% Deafness	Occupation	% Deafness
Choppers and caulkers	64-84.1	Can tossers	24.8-42.0
Riveters inside machine bodies	100.0	Riveters	56.0-87.5
Riveters in a shop	62.8	Various occupations in machine construction and metal working industry	50-85
Weavers	57.2-70		

working with hydraulic hammers, those working at automatic turret lathes, at stamping machines, in rolling mills and many other occupations. It is not possible to give a comprehensive idea of the condition of the organ of hearing in workers /262 in many so-called noisy occupations, as examinations were often conducted on different planes and a conclusion was often drawn by the greatest reduction of perception of one or other frequency, which, is without doubt, interesting, but more from the standpoint of an etiological factor. The most interesting and generalized multiple data of both personal observations and those of other authors with respect to fatigue and deafness are those of Ya. S. Temkin and V. G. Yermolayev.

The observations indicate that fatigue is a definite state of the acoustic analysor, developing as a result of the effect of noise, recovered after rest, which does not occur in deafness — although even with the latter, there is a certain potential reserve which can be seen in studying the organ of hearing before and after work. The farther these two curves are from each other, the greater the potential reserve and the less pronounced is the deafness, and vice versa. This is why it is so important, as indicated by Ya. S. Temkin, that the study of the functional state of the acoustic analysor be conducted before work (after long rest) and immediately after.

It is very important to localize the damages (which a specialist can do), to determine the degree of damage and the progression of deafness. From the standpoint of industrial hygiene, these questions are also important, as is the connection between the etiological factor and the development of deafness.

B. A. Krivoglaz, A. A. Model' et al., observed hearing disorders in 28.5% of workers in a spinning-weaving factory and a significant reduction of the auditory function in only 1.9%. Pronounced forms of neuritis of the auditory nerves are observed only in workers with more than 10 years job experience, but cases of early deafness were noted which, evidently, is connected with heightened sensitivity to noise. In this group of workers, reduction is primarily noted in the perception of high frequencies, and only with a long work record was the threshold to low frequencies raised (14 dB with 6-10 years work experience and 20 dB with more than 10 years).

With specially conducted observations, the authors established that hearing disorders of workers in the spinning-weaving industry are due to damage to the sound-perceiving apparatus.

G. Z. Dumkina (1965) noted that perception of high (300-8000 Hz), low and medium frequencies was changed very little or not at all in pistol shooters and submachine gunners. As with workers in other noisy occupations, a change /263 was noted in their auditory function with job experience, but only after 5 years. As the degree of deafness was more pronounced and developed earlier in submachine gunners than in pistol shooters, this once more emphasizes the importance of noise intensity in the development of deafness.

The reduction of hearing acuity after 5 years of work is 21-50 dB in the high frequency range, but the reduction of perception of high frequencies of 40-50 dB is encountered in isolated cases. In submachine gunners and pistol shooters, no parallelism was observed between changes in the functional state of the central nervous system and its autonomic section and changes in the auditory function.

N. T. Svistunov examined the condition of the organ of hearing in electrical machine testers. One group was in contact with wide-band noise with energy equally distributed in the spectrum band (100-800 Hz), at a level of 102 dB. The second

group was subjected to the effect of high-frequency noise with maximum energy at 1250-2500 Hz, general level 113-120 dB. A third group worked in conditions of wide-band (200-3600 Hz) noise, with an intensity of 94-120 dB. In all groups, the author found reduced auditory function, progressing with work experience. The threshold of auditory sensitivity increased; with less than a year of work, the reduction of hearing acuity was maximum (22 dB) at a frequency of 6000 Hz, in testers with 1-5 years experience, the increase was 12 dB at a frequency of 4000 Hz. With experience increased to 10 years and more, an increase was again noted in the threshold to 16 dB at the same frequency. However, the most pronounced was the reduction of perception of a 2000-8000 Hz frequency.

The research of the author showed that noise leads to the development of deafness in machine testers and that there is no selective increase of the threshold at a frequency of 4000 and 2000 Hz, but there is, although to a slight degree, at lower frequencies. The fact that the contingent of workers was young (22-28 years of age and none over 37) must also be taken into consideration.

In testing several groups of workers by the tonal audiometry method, a reduction in the perception of low tones is also observed. As a rule, this is seen in those workers affected simultaneously by noise and vibration. The audiogram assumed a gently sloping character with job experience, although the reduction of perception is somewhat more pronounced at high frequencies.

N. N. Pokrovskiy noted in workers subjected only to the effect of noise and to vibration and noise the development of deafness at practically the same stage of work. According to his data, the percentage of deafness was quite high (about 62.3%). The development of the disease proceeds rapidly. Already at 3 years work experience, the hearing loss at a frequency of 1024-2048 Hz is 15-17 dB, and at a frequency of 4096-8102 Hz it is 23-26 dB. In succeeding years of work, perception of 1024-2048 Hz frequencies is affected, the audiometric curve is evened out, a flattened trough is formed in the area of 1024-8192 Hz. /264

Interesting data were obtained by A. G. Rakhmilevich with regard to the combined effect of noise and vibration on the acoustic analysor. Observed in workers during the joint effect of these two factors — identical parameters of vibration, but different intensities of noise and work regime — were different changes in the threshold of audibility. It is noteworthy that noise of low intensity

(70 dB), which generally does not cause significant changes in the acoustic analysor, leads to considerable shifts during a simultaneous effect with vibration. Of undoubted interest is one more observation of the author during the combined effect of acoustic and vibration factors — at first perception is lowered not only at frequency of 4096 Hz, but also of 128 Hz, and then at other frequencies. The reduction of perception of low frequencies proceeds as in air and bone perception.

One of the methods of evaluating the condition of the acoustic analysor is to determine the functional mobility of its cortical link. This is the method of determining the critical frequency of sound bursts (the critical fusion frequency) (CFF), which has been widely used recently. The method is based on the theories of A. A. Ukhtomskiy about the functional lability of tissues, the characteristics of the rate of those elementary reactions which accompany the physiological activity of a given analysor. He felt that the most suitable method of studying lability is to determine the greatest number of electric oscillations which a given apparatus can reproduce in 1 second.

As is known, the lability of tissue in the process of stimulation can change in different directions, characterizing the state of excitation of inhibition. In proportion to the entry of the system into working order its lability increases, whereas the development of inhibition leads to reduced functional mobility. The more oscillations the tissue gives, the more mobile it is.

P. O. Makarov called the ability to differentiate a discontinuous discrete structure "discretability." The discretion of the analysor is characterized by that frequency of stimuli of a certain intensity, by which they are judged as discontinuous. P. O. Makarov (1959) pointed out that "we still cannot assert that lability of analysors, determined by the critical rhythm of converting a /265 recording of interruptedness of a stimulus to a recording of discontinuity, corresponds to the greatest number of stimuli per unit of time in the cortical cells of the analysor. The question is much more complex, although, undoubtedly, the lability of the analysors characterizes the rate of reactions and the interaction of nerve structures of the analysors."

Using this method, L. Ye. Milkov (1961), determining the critical frequency of sound bursts in workers subjected to the effect of noise, found CFF reduced with work experience.

A. I. Vazhzhova (1962) detected in machine operators subjected to the effect of intense high-frequency noise significant and persistant reduction in the critical frequency of sound bursts, indicating a change in the mobility of basic nerve processes in the auditory analysor.

Z. F. Panayotti (1963) determined the critical frequency of sound bursts in testers subjected to the effect of medium-frequency noise with an intensity of 60, 70, 80 and 100 dB for 2 hours. The author established a definite dependence of the CFF indices on the intensity of the sound stimulus, individual sensitivity and the time of the noise effect. With noise intensity of 100 dB, critical frequency in 2 hours was reduced 22% (in comparison with normal), with an intensity of 80 dB — 6.5%. After the effect of a noise with an intensity of 60 dB, the critical frequency was only slightly reduced after the test, and in 30 minutes it was restored to the original values.

The studies of the author showed that the effect of noise with an intensity of 100-80 dB for two hours leads to persistent deterioration of the course of nerve processes in the central link of the acoustic analysor. Residual effects are maintained only two hours after 70 dB noise, and there are none with a noise intensity of 60 dB.

At the same time, auditory sensitivity with a noise intensity of 100 dB is reduced 20 dB in both ears to the perception of 2000 Hz, 40-43 dB at a frequency of 4000 Hz, and 27 dB at a frequency of 8000 Hz., and after 2 hours it is restored to normal. Perception of frequencies of 125-1000 Hz remains practically unchanged. Noise with an intensity of 80 dB causes significantly less reduction of the auditory function; thus, it changes 8 dB for the perception of 4000 Hz frequency, and 12 dB for a frequency of 8000 Hz; auditory sensitivity is restored accordingly with intense noise in 1 hour and 30 minutes. With noise intensity of 70-60 dB, auditory sensitivity is maintained and its fluctuations remain normal.

Thus, the author, using the method of critical frequency of sound bursts and tonal audiometry, showed that after a 2-hour effect, the sequence reaction is maintained in the cortical link of the analysor for quite a long time. /266

Ye. B. Reznikov also used the method of determining CFF, but on stamping machine workers subjected to the effect of pulse noise. The average value of the

TABLE 48

DISTRIBUTION OF CRITICAL FREQUENCY OF SOUND BURSTS IN STAMPING MACHINE WORKERS IN THE DYNAMICS OF THE WORKING DAY (AFTER YE. B. REZNIKOV)

Work exp. yrs.	No. of exami- nations	Time of Study	Value of CFF					
			55-57	68-80	81-93	94-106	107-119	120-132
Under 5	42	Before work	—	4	5	24	6	3
		After work	2	16	7	14	3	—
5 - 10	23	Before work	—	5	12	6	—	—
		After work	2	10	8	3	—	—
Over 10	30	Before work	—	15	11	4	—	—
		After work	11	13	14	2	—	—
Control Group	50	Before work	—	—	—	16	24	10
		After work			3	17	22	8

critical frequency of sound bursts was lower in the stamping machine workers than in those of the control group, by approximately 20 bursts /sec. After the end of work, it is still reduced, and the number of persons with reduced functional mobility of the auditory analysor is increased. Table 48 gives data on the distribution of CFF values in stamping machine operators.

Ye. B. Reznikov found a correlational connection between the value of the critical frequency of sound bursts and a given condition of auditory sensibility in stamping machine operators, obtained by the tonal audiometry method, which indicates the presence of changes in the peripheral as well as the central section of the acoustic analysor.

In groups of workers in noisy occupations for less than 5 years, N. Svistunov observed no parallelism between reduction of the auditory function, which might even be considered as the initial symptoms of deafness (1st degree according to Rakhmilevich), and changes in the functional state of the central nervous system. Functional disturbances of the latter were very pronounced and gave a basis for assuming that they precede shifts in the peripheral section of the acoustic analysor.

N. N. Pokrovskiy set himself the task of establishing the interconnection /267 between the degree of change in the auditory and other functions of the organism. Of special interest is the relation he found between the condition of the central nervous system and the acoustic analysor. It is known that persons suffering an astheno-neurotic condition are very sensitive to noise.

Disturbances in various analysor systems are observed during the irritable weakness syndrome, the basis of which is weakening of the cortical activity of one or other analysor. It is known that sensory disturbances are very common during the irritable weakness syndrome.

N. N. Pakrovskiy observed the syndrome of irritable weakness in a rather large percentage of the 151 boilermakers he examined. To one degree or another, these workers also suffered from deafness.

This method was used in the experimental conditions of S. V. Alekseyev and G. A. Suvorov (1965) to characterize the effect of noise of various spectra and character (impulse). A comparison of the data obtained implies that pulse noise causes more pronounced changes in the central section of the acoustic analysor than stable noise. The critical frequency of sound bursts under the effect of pulse noise is reduced more significantly. Its definite dependence is established on pulse recurrence frequency.

All these data indicate very demonstratively that the use of this method, together with tonal audiometry, gives a more complete idea of the effect of noise on the acoustic analysor.

S. V. Alekseyev, after the effect of noise with maximum sound energy at frequencies of 300, 500 and 700 Hz, found a pronounced change in the mobility of nerve processes in the acoustic analysor, using the method of determining critical frequency of sound bursts . With noise intensity of 80 dB with maximum at a frequency of 300 Hz, it was reduced 5%, at 500 Hz — 7.5% and at 700 Hz 9.9%. When intensity is increased to 90 dB, maximum reduction of CFF with maximum sound energy at a frequency of 700 Hz and minimum at 300 is 21 and 14% respectively. The reduction of the cirtical frequency of sound bursts does not exceed 3-4% when intensity is 70 dB.

S. V. Alekseyev studied the thresholds of auditory sensitivity in the same subjects. The data he obtained also indicates that change in auditory function is due not only to processes in the peripheral ending of the acoustic analysor, but in the central as well.

These data, with the use of the two indicated methods, are very illustrative of the advantage of their combined application. /268

Vocal audiometry is widely used. There is the opinion that the perception of a voice in noisy conditions at a distance of 1 m indicates absence of the harmful effect of noise of a given intensity.

A. G. Rakhmilevich conducted interesting studies to reveal the maximum effect of noise on the perception of individual sounds of not only the vocal range. We present his data in this section because the research of A. G. Rakhmilevich should attract the attention of all those interested in deafness, its determination and the elimination of those frequencies in the spectrum of industrial noise which are most dangerous and undesirable. The work of Fletcher (1929) is known, which established the relation between the intensity of masking noise and the degree of voice intelligibility in noise conditions.

To do this, A. G. Rakhmilevich recorded audiograms directly in the industrial noise situation, which enabled him to determine its masking effect on the perception of individual parts of voice and auditory areas as a whole.

The author feels that the greatest change in the audiometric curve must be below those tones which predominate in the noise spectrum. This method of study was called noise audiometry. The method was first introduced by Langenbeck (1956). It can be used with great success both in studying normal hearing and when there is damage to the sound-conducting apparatus of the hair cells of the organ of Corti. In this case, the noise audiogram decreases by the number of decibels equal to the intensity of white masking noise. With damaged cochlear ganglion and nerve stem, the noise audiogram falls below this level.

A. G. Rakhmilevich recorded noise audiograms in workers who had varying degrees of occupational deafness. Analysis of the audiograms and the noise spectrum established that the masking effect of the noise depends on the intensity of the

tones appearing in it. In examining a large number of workers, the author did not find identical noise audiograms; in people with pronounced deafness, they are below the level of shop noise. Individual noise audiograms in persons with normal hearing contain 10-15 dB variations in the level of thresholds in individual frequencies, and those with occupational deafness — as much as 30-35 dB.

In persons with II and III degree deafness, A. G. Rakhmilevich found /269 thresholds of auditory sensitivity somewhat exceeding the intensity of industrial noise.

As voice intelligibility is very important in industrial shops, it becomes necessary, however approximately, to evaluate the level of noise according to the intelligibility of speech.

Levels have been established at a distance of 1 m: scream at 90 phons, loud voice at 80, quiet voice at 45, whisper at 30 phons.

When the distance is approximately 0.1 m, the force of the sound (according to the rule — the force of sound is inversely proportional to distance) increases 20 dB, but the loudness of speech decreases from 80 to 74 phons. Speech becomes unintelligible if noise with a level up to 100 phons exceeds it by 15-20 phons (loud voice).

Determining the intelligibility of speech with mono- and binaural hearing, a study of adaptation, conditioned and unconditioned reflexes to sound can serve to study the functional state of the cortical section of the acoustic analysor.

The use of the acoustic reflex in the problem of occupational deafness and protecting the organ of hearing is interesting. As we have pointed out, an intense sound causes the muscles of the middle ear (mm. stapedius, tensor tympani) to contract, as a result of which the amplitude of vibrations of the auditory ossicles is reduced and thus the cochlea is protected from damage. The latent period of excitation of m. stapedius is 10-15 μ sec. In m. tensor tympani it is considerably longer (maximum contraction of the muscles occurs in 100 μ sec, the duration of the acoustic reflex after a sound pulse from initiation to extinction is less than 1 second). It is assumed that the protection offered by this reflex is on the whole 10 dB or more at frequencies of 1000 Hz, and for

persons with a heightened auditory sensitivity, it can reach 50 dB. On the basis of the protective role of these muscles and their physiological characteristics, many researchers are attempting to explain the mechanism of the effect of pulsed noise. They have concluded that if the time of the pause between pulses is slightly greater that the extinction time of the acoustic reflex, and if the formation time of the pulse is less than the time of excitation of the muscles of the inner ear, such pulse noise will cause a greater increase in auditory thresholds, i.e. it will be a stronger stimulus. Ward, Glorig, Sklar (1958), Ward, Glorig, Selters (1960, Ward (1962a,b) established that very short (2 μ sec) intense sound pulses cause shifts in the auditory thresholds in relation to the length of the pause; the longer the pause between pulses, the more pronounced they will be. The authors attribute this fact to the reflex cycle of muscles of the inner ear. With a high frequency of pulses developing after the first pulses, reflex contraction of muscles is also maintained during succeeding pulses, if the pause between the two pulses is shorter than the dampening of the reflex, /270 then the reflex disappears during longer pauses.

Fletcher, Riopelle (1960) studied the possibility of protecting the ear from gun shots by an acoustic reflex. The latter was caused by a tone with a frequency of 1000 Hz, with an intensity level of 98 dB, which was given for 200 msec before the shot. The test lasted 7 minutes, during which time 100 shots were fired. The mean peak level of pulse noise was 132 dB. The level of the auditory threshold changed before and after the shot. In one series of tests, the ears of the subjects were not protected, in the other — they were protected by the acoustic reflex, and in still another — with earphones. It was found that in the first series of tests, the auditory thresholds were raised 19-23 dB; in the second series — 6.27 dB; in the third — 2.5 dB. The authors concluded that the acoustic reflex significantly protects the ear from intense pulse noise, although to a lesser degree than earphones.

No less interesting are the results obtained by Christman and Simon (1961) who studied the possibility of practical protection against industrial pulse noise by stimulating the acoustic reflex The authors emphasize that protecting the ear with the acoustic reflex has a number of advantages over earphones, namely; they are protected only at the moment of the noise pulse; therefore, personal contact is not disturbed in the pauses; the tone can be activated automatically; to a certain degree the tone also warns the worker.

The protective role of the acoustic reflex was also shown in other works.

Coles and Rice (1966) even suggested testing two signal warnings: one 5 seconds before the sound pulse so the next sound would not be unexpected, and then another — 150 msec before the sound pulse to cause the acoustic reflex. The authors feel that the application of these two kinds of warnings would be very effective.

The protective role of the reflex contraction of the middle ear muscles is noted by Ya. S. Temkin (1968), suggesting that the frequent lack of temporary increase in the thresholds of auditory sensitivity in experienced workers can be attributed to weakening of reflex contractions of the muscles as a result of permanent changes which have developed.

It has been suggested that the acoustic reflex does not play an important role in protecting hearing from pulses recurring with relatively long intervals. This suggestion was made on the basis of experiments in which a connection was established between the acoustic reflex and the temporary increase of auditory thresholds from the effect of various kinds of pulse and stable noises; while the correlation between measurements of acoustic reflexes was good, the correlation /271 between measurements of temporary increase of auditory thresholds was poor, and it is probable that no connection between the force of the acoustic reflex and the temporary increase of the auditory threshold existed.

Ye. Ts. Andreyeva-Galanina and G. A. Suvorov (1969) feel that the role of a signal stimulus is that it causes the muscles of the inner ear to contract and transmits certain information to the organism, thereby helping it to predict subsequent events and adjust to them optimally. This is verified by tests with warning light and sound signals of weak intensity during the effect of an aperiodic noise stimulus. Despite the fact that the stimuli used could not directly cause an acoustic reflex, the protective effect of the warning signals was clearly established. It is noted that the most effective influence of the sound stimulus is observed when it precedes a pulse noise by 300 msec, and that of a light signal (flashing of a neon tube) by 500 msec. When the time is shortened, the effectiveness of the acoustic reflex is sharply reduced.

These studies verify the data of the authors about the protective role of a warning signal; however, the authors do not agree with the simplified interpretation of the observed phenomenon that attributes the basic protective role to the muscles of the inner ear and completely ignores the protective-adaptation activity of the central nervous system.

CHAPTER VI

MEASURES TO CONTROL NOISE

In all cases when noise exceeds the permissible limit, measures must be undertaken in the factory to control it. It is especially important to control industrial noise, which is generally not as simple as it sometimes seems. In each individual case, it is considered separately. Measures to reduce noise are based on various principles, the choice of which depends on the sources of the noise and the industrial process. It is possible to discuss only a few of them, combined in a group of general methods and means of controlling noise. /272

Controlling the harmful effect of industrial noise includes a whole complex of measures consisting of both medical and technical methods and means of control.

Medical Prevention[1]

One of the most important measures in the medical prevention of the harmful effect of noise is conducting preliminary and periodic medical examinations. Regular examinations play a special role in preventing noise pathology.

By order of the USSR Ministry of Public Health, persons who start to work in noisy factories, as well as those who work under conditions affected by intense industrial noise, undergo compulsory preliminary and periodic medical examinations.

---

(1) The section "Medical Prevention" was written in collaboration with M.L. Khaymovich.

By order of the USSR Minister of Public Health No. 400 of 30 May 1969, in factories with an excessive level of noise in any octave band, periodic medical examinations are made of the workers at the following times, depending on the level of excess:

a) below 10 dB — once every 36 months [1]
b) from 11 to 20 dB — once every 24 months
c) over 20 dB — once every 12 months

Involved in the preliminary examinations before starting to work and the periodic medical examinations are the otolaryngologist, neuropathologist, and therapist (when indicated), with compulsory audiometric testing, and determination of hemoglobin, leucocytes, and sedimentation rate. /273

It is necessary to conduct tonal and voice audiometry to get a good idea of the function of the acoustic analysor. The hearing study must be conducted, as a rule, before work with noise starts, i.e., after the organism has had a long rest from the sound, and after it ends.

Medical counterindications for admission to work, according to the order of the USSR Minister of Public Health, No. 400, of 30 May, 1969, are the following:

1. Persistent reduction of hearing, even of only one ear, of any etiology.
2. Otosclerosis and other persistent diseases of the ear with a clearly unfavorable prognosis for hearing.
3. Pronounced disturbances to the vestibular function of any etiology.
4. Pronounced neuroses (neurasthenia, hysteria, psychasthenia).
5. Pronounced autonomic dysfunction.
6. Organic diseases of the central nervous system, including epilepsy.
7. Neuritis and polyneuritis.
8. Mental diseases and psychopathy.
9. Diseases of the cardio-vascular system, hypertonic disease, persistent vascular hypotonia, stenocardia.
10. Acute ulcer disease of the stomach and duodenum.

---

[1] Taking into account work in other plants under conditions of industrial noise.

The preliminary and periodic examinations of the workers are organized and conducted by the medical units and polyclinics attached to the factories, and in their absence — by the territorial preventive treatment centers, serving the region where the factories are located.

The purpose of conducting preliminary medical examinations before admittance to work is to make a thorough and extensive investigation of the state of health and decide the possibility of using industrial and office workers in factories and occupations covered by order No. 400.

Periodic medical examinations provide dynamic observation of the state of health of the workers and reveal the first signs of occupational disease of noise etiology.

The persons undergoing the medical examinations are considered every year at each plant by the health and epidemiology stations in conjunction with the trade-union organization. The health and epidemiology station indicates the names of the shops and occupations, as well as the number of workers, undergoing medical examination and gives the characteristics of unfavorable factors. On the basis of this, the administration of the plant compiles a list of names of the workers /274 undergoing examination and directs them, and the preventive treatment center compiles a list of the workers and calendar dates when the periodic medical examinations will be conducted. The administration of the plant is responsible for the prompt and organized arrival of the workers in "noisy" occupations to the medical institution, and the preventive treatment center is responsible for the quality of the examination. When the preliminary examinations are conducted, a medical examination card is filled out. The doctors conducting the periodic medical examinations must know the working conditions, the nature of the factor and possible occupational pathology caused by the effect of noise.

Considering the importance of the dynamics of subsequent observations, data must be carefully filled in about complaints and the objective examination of the worker. The condition of ENT-organs is described in detail, particularly otosclerotic data and the results of studying the function of the acoustic analysor. Special attention must be given to the functional state of the central nervous and cardio-vascular systems, as well as the gastro-intestinal tract. The examination of specialists should be reflected in a generalized diagnosis and conclusion.

Basic and attendent diseases and the etiology are indicated in the diagnosis. Future working capacity is decided.

Workers subjected to the effect of intense industrial noise and undergoing periodic examinations should be under dispensary observation by center otolaryngologists. According to order No. 400, a control card must be filled out for each worker and kept by the center otolaryngologist or the neuropathologist. It would be better if both specialists had this card, as this would aid in the future determinations of the connection between changes in the acoustic analysor and in the functional state of the nervous system.

Periodic medical examinations are especially important in accommodating the development of occupational pathology, caused by the effect of intense noise, and the recovery of the damaged functions. As a result of these examinations, health treatment measures can be planned, — improvement of industrial health conditions, directed toward reducing the level of noise to established standards, proper organization of work and rest, transfer to a job in favored conditions, health resort treatment. The value of the latter is still not sufficiently evaluated, while its role is undoubtedly great.

When the tests in the periodic examination are finished, all the medical material obtained is reviewed in a special final meeting of the commission. This /275
commission must be composed of the factory doctor, the chief doctor of the treatment center or his assistant, the director of the safety engineering department and a representative of the factory-and-workshop committee. On the basis of data from the periodic medical examinations, taking into account the conditions of work, daily life and industrial characteristics, individual conclusions are made about the connection between detected disease and the occupation, and necessary prophylactic measures and efficient organization of work are recommended.

Prompt and thorough periodic medical examinations and preventive treatment measures help prevent the development of occupational diseases.

The preliminary medical examinations also play an important role in preventing the development of pathology. Their basic purpose is to expose unhealthy conditions, which increase the danger of the effect of noise on the man in industrial conditions and decide his occupational suitability. This question is answered

from two standpoints: 1) when the state of health will not satisfy the requirements imposed by the occupation; 2) when the effect of the noise can strongly worsen already existing disease. In making the preliminary medical examination of the worker entering a "noisy" occupation, the doctor must first of all consider the general state of his health, his functional resources. For this he must have a good understanding of the health and hygiene characteristics of "noisy" occupations and the working conditions of each shop. Workers accepted for noisy industries must be healthy, no younger than 18 years of age, in accordance with the list of contraindications.

Technical Methods and Means of Controlling Noise

At the present time, a great deal of experience has been accumulated in controlling noise in various industries, which has also been reflected and discussed in detail in a number of important monographs (G.L. Navyazhskiy, 1948; Ye.V. Bobin, 1964; I.I. Slavin, 1955; T.A. Orlova, 1965; A.I. Vozhzhova and V.K. Zakharov, 1968, and others). As the authors have pointed out, noise must be controlled in the following directions: 1) reduction of noise at the source of its development; 2) soundproofing and sound absorption, vibration proofing and vibration absorption, installation of silencers; 3) replacing equipment with less noisy machines, efficient arrangement of equipment and planning of operation time; 4) individual means of noise protection.

Noise control is a complex problem; noise sources are extremely varied; /276
therefore, measures are separately or complexly implemented in each specific case.

First of all, obvious sources of noise in the shops must be eliminated. The noise source is usually vibration of various components, which develops under the effect of impacts, friction forces, or variable mechanical forces. It is most difficult to eliminate noise in percussion machines and units. At the same time, the only way to control the noise of such equipment is to improve its design. It is most radical to change the technological process to eliminate impacts, as only a very slight reduction of noise is possible in percussion units and that only by quite cumbersome equipment. Therefore, it is recommended that technological processes based on the use of percussion instruments be replaced by percussionless equipment, which is also quiet. For example, ordinary riveting, performed by riveting hammers, would be replaced by hydraulic or welded riveting, stamping —

by molding, manual straightening of sheets — by rolling, etc.

In a number of cases, auxiliary operations can be much noisier than the basic ones. For example, metal stampings and electrodes falling in metal containers make more noise than the process of making them. Dropping components must be replaced by depositing them by a track. Tracks and containers made of noiseless material would significantly reduce this noise. Alloys made with manganese and magnesium are less noisy materials with great attenuation. Chrome-plating steel components also reduce their sonority. Noise can also be reduced by replacing noisy components with noiseless ones — made of textolite, wooden plates, plastics, etc.

Noise and vibration are reduced by replacing rapid reciprocating motions by evenly rotating motions. In this way, the noise of looms (the shuttle) and nailers (the striker) can be considerably reduced. Replacing reciprocating motion with rotary in the braiders, used in cable factories, also will significantly reduce noise.

An effective means of controlling vibration and noise is reducing the spaces between adjoining components by injecting materials which increase friction forces and thereby offer resistance to movement. Among the methods directed toward reducing vibration, a significant role must be attributed to damping (reducing vibrations by absorbing part of the energy). The essence of damping is that the /277
vibrating surface is covered with a material with great interior friction. The best damping materials are rubber, cork, bitumin, felt, etc. They dampen high sounds especially well. In relation to the value of the friction forces, the amplitude of vibrations changes evenly and decreases more, the greater are the friction forces. The reduction of high frequencies is extremely important with respect to health, as the remaining low frequencies in the noise spectrum do not cause such a negative effect. Using this means of damping noises of automatic turret lathes and straightening machines, the Noise Laboratory of the All-Union Scientific Research Institute of Work Safety of the VTsSPS successfully reduced the general level of noise 12 - 18 dB, and high sounds 20 - 30 dB. Damping can be successfully used in several percussion processes, particularly in straightening metal sheets, tinning ship operations, etc. Sheets are usually straightened on a massive anvil plate, mounted on a wooden platform. Unevenness in the platform produces a space between the metalic plate and the platform. Therefore, when

the sheet being straightened is struck, a vibration is produced which can be greatly reduced if felt is placed between the platform and the plate. Viscous fluids are sometimes used to damp noise, in particular machine oil. Still better effects are obtained with the simultaneous use of several kinds of noise damping. Packing the work in process in damping padding should be widely used in trimming operations, especially in trimming sheet steel.

To increase the effectivenss of damping, the damping material must be tightly attached to the vibrating surface.

Damping materials have various characteristics, mechanical, and acoustic properties. The principal demands made of damping materials are: low cost, high effectiveness, low weight, ability to stick firmly to metal and to protect it from corrosion.

About 30% of equipment in industry cause noise of a high level because of imperfect technical maintenance of the mechanisms. Therefore, improving current maintenance is an important factor in reducing noise.

In 1966, a new GOST 11870-66 was developed and approved, "Machines. Noise characteristics and methods of determining them," to go into effect 1 January 1968.

The new GOST established the composition and methods of determining the noise characteristics of machines, mechanism, means of transportation, technological equipment, mechanized instrumentation, and of individual units (bearings, reducers, etc.), which in an unaltered operating regime create stable noises in the air. /278
The standard is not extended to determining noise characteristics of machines in motion or machines whose noise has a pulse character. Now, determining the noise characteristics is obligatory in making prototype tests. Noise characteristics must be indicated in the technical documentation attached to the machine — in the machine certificate. This very important legislative measure will undoubtedly help effectively control industrial noise developing at the source itself.

In a number of cases, when changes in the technological process and measures to control noise at its source cannot significantly reduce noise, the noise must be localized at its site of development. For this, sound-absorbing and soundproofing design and materials widely known in modern construction are used.

It is much easier to reduce or eliminate noise by isolating it. In order to be sufficiently effective, it is first of all necessary to know the nature of the noise or sounds, as the means of weakening it are closely related. Noise can penetrate by air through existing slits, openings and pores in the construction, etc., through an enclosure which vibrates under the effect of moving pressure, and finally, by means of vibration. Methods of reducing sounds transmitted by these means are varied. Therefore, it is very important to determine which noises must be controlled.

The method of controlling noise by special constructions to prevent the distribution of noise by air in a certain room, or by constructions to block the transmission of sound from one to another insulated room is called soundproofing.

Air noises can be weakened by constructing special casings around the machines or by placing the noise source in a room with massive walls without cracks or openings.

I.I. Slavin (1956) points out that soundproof constructions should reduce the level of source noise 30 - 40 dB.

Even a comparatively thin wall or casing is enough to insulate a high frequency noise, while thicker construction is needed for low-frequency noises. Light enclosures have a high natural vibration rate. Therefore, they resonate under the effect of corresponding noise frequencies, which is sometimes observed in casings intended for soundproofing and made of a thin sheet of iron. These enclosures not /279
only do not reduce noise, but even intensify it. In practice, reduced soundproofing is often observed at low (under 250 Hz) and high (over 2000 Hz) frequencies because of resonance vibrations of partitions.

To eliminate similar phenomena, the surface is sometimes lined with materials with great internal friction — rubber, cork, felt, etc. Materials which are good inhibitors of the propagation of air noise are heavy and have a dense structure. The soundproofing properties of barriers are characterized by so-called intrinsic soundproofing, which designates the degree to which a sound is weakened in decibels. The effectiveness of a single soundproofing enclosure almost entirely depends on its weight per 1 m^2. The kind of material from which a given barrier is made is

not very important. A graph of the dependence of soundproofing on the weight of construction shows that if the weight is increased 2 times, the soundproofing is increased 3 - 4 dB. Much greater soundproofing can be attained by using complex constructions. This is attained by separating the wall into several layers with air layers or making them out of friable materials (felt, wadding, etc.). A wall made of this layered construction gives 6 - 8 dB better soundproofing than a monolithic wall of the same weight. In layered constructions, there must be a stable connection between the individual layers; this is achieved by padding made of rubber or other vibrationproof materials.

In industry, sound and vibration proof floors are often specified. These are primarily penetrated by corpuscular or impact sounds. These are weakened by the use of resilient padding under the floors. These should not be in close contact with the walls and other load-bearing structures of the building to avoid a solid connection with them. Proper construction of floors reduces the level of impact noise under the floor 37 dB (I.I. Slavin). To reduce the transmission of vibrations of engines, compressors and other units, they are mounted on shock absorbers in the form of steel springs, or rubber, cork, commercial wadding or asbestos padding. To reduce the transmission of vibrations through the bottom, the machines are mounted on a special base. Shock absorbers must be designed for each specific case. Vibrations which are spread through pipes and conduits are weakened by filling slits in individual sections with soft insertions made of rubber, canvas, etc. Vibration of metal surfaces can be reduced, as has already been noted, by damping.

The most common means of extinguishing vibrations has been a special anti-noise mastic (No. 579 and 580), manufactured by varnish and paint factories, prepared on a bituminous base and applied to the surface of the metal in two or three layers to a thickness of 2 - 5 mm. /280

Damping is widely used for covering ventilating ducts, metal casings, etc.

In industrial conditions, sound absorption is often used along with sound proofing. Noise is absorbed by sound-absorbing materials, most often porous. These linings are recommended for typing offices, computer stations, telegraph equipment, marine engine compartments and other small noisy rooms (400 - 500 m^3). The reduction of noise with such linings does not exceed 7 - 8 dB.

Materials with good sound absorbing properties are comparatively light and simple. Sound absorbing materials often cover sound proofing structures, in this case the structures will operate as sound absorbers and sound proofers.

Absorption capacity is characterized by the coefficient of sound absorption "α" which is the ratio of the sound energy absorbed by the material to the energy falling on it. Coefficients of sound absorption (Table 49) of various materials are measured experimentally at various frequencies in reverberation chambers or a special tube.

As can be seen from Table 49, sound absorption depends on the thickness of the sound-absorbing material, its properties, and on the arrangement of the room. It can be assumed, that sound absorption for low-frequency sounds is roughly proportional to the thickness (up to 7 - 10 cm); for high frequencies, sound absorption depends less on the thickness, and 2 - 3 cm thickness is sufficient. The air gap behind the layers of material also helps increase sound absorption at low frequencies.

To increase mechanical strength and protect the absorber from damage, the material is covered with a perforated coating of metal, plywood, cardboard, etc. The perforations in the outer covering can be round (4 - 5 mm diameter), square or slotted. The combined area of the openings should be 25 - 35% of the total area of the sheet. It must be remembered that paints mixed in water do not affect the sound absorption of perforated or nonperforated structures, unlike oil paint which covers the pores and impairs the sound absorbing characteristics of the material. The majority of thermal insulation materials, constructed with the pores covered, are poor sound absorbers. It is best to place sound absorbing material close to /283
the noise sources, as the effectiveness of the material increases in areas of high sound pressures.

In large factory rooms noise can be reduced by constructing sound-absorbing barriers and solid sound absorbers, hung over the noisy units (Figure 68). In this case, sound absorption is increased approximately twice in comparison with placing the sound absorbing material on the ceiling and walls.

In selecting a sound-absorbing material, we must keep in mind that the material must be noninjurious to the health of the workers, long lasting, have good

TABLE 49. COEFFICIENTS OF SOUND ABSORPTION OF STRUCTURES AND MATERIALS

Structure or material		Specific weight, kg/m^3	Thickness, mm	Frequencies, Hz: 128	256	512	1024	2048
				Mean values of coefficients of sound absorption				
Various structures and materials	Concrete	—	—	0.01	0.01	0.02	0.02	0.03
	Sandstone plates	—	—	0.01	—	0.015	—	0.02
	Brick plastered wall	—	—	0.01	0.01	0.02	0.03	0.03
	Pinewood boards	—	18	0.1	0.1	0.1	0.08	0.08
Sound absorbing plasters and plates	Plate made of acoustic plaster located 50 mm from the wall	—	25	0.30	0.50	0.86	0.45	0.50
	Pemsolite and pemsolite plates in magnesite cement	600-800	25	—	0.35	0.42	0.43	0.46
Sound absorbing TsNIPS* plates	Attached to the wall	850	30	0.23	0.27	0.44	0.58	0.50
	Placed 50 mm away	850	—	0.52	0.61	0.63	0.50	0.47
	ATsP, AGP** Acoustic plasters	650-750	25	0.12	0.27	0.31	0.32	0.38
	Foam concrete plates	350-450	—	0.20	0.40	0.45	0.45	—
	Perforated plates	200-300	30	0.28	0.45	0.55	0.60	0.62
Mineral wadding and derivatives	Sound absorbing plates with a layer of mineral wadding 100 mm thick (diameter 4 mm spaced 20 mm from the center)	—	—	0.48	0.60	0.66	0.62	0.50
	Mineral wadding plates	350-400	30	0.24	0.35	0.38	0.41	—
	Mineral wadding	150-200	28	0.18	0.30	0.68	0.75	—
	Mineral wadding, granulated	100-200	28	0.20	0.30	0.46	0.65	0.68

(Continued on following page.)

(*) Translator's note: This designates Central Scientific Research Institute of Industrial Structures.

** Translator's note: ATsP — expansion unknown; AGP — automatic field damper.

/281

/282

Structure or material		Specific weight kg/m³	Thickness, mm	Frequencies, Hz: 128	256	512	1024	2048
				Mean values of coefficients of sound absorption				
	Mineral felt	150-200	40	0.40	0.49	0.61	0.67	0.69
	Mineral cork	300-350	30-80	—	0.35 to 0.60			—
Wood fiber plates	Perforated plate ϕ 5 mm, spaced 20 mm	150-250	25	0.03	0.24	0.55	0.44	0.52
	Arborite, smooth plates, laid on the wall	150-250	25	0.02	0.29	0.40	0.46	0.45
	Wood fiber plates, orgalite	200-250	12.5	—	0.30	0.42	0.53	0.69
	Wood fiber plates (with sawdust)	200-250	35	—	—	0.21	0.41	0.46
	Wood fiber plates ROSNIIMS*	250-270	25	0.45	0.35	0.39	0.40	0.49
Various materials	Canvas, hung 150 mm from the wall	—	—	0.10	0.12	0.25	0.33	0.15
	Cotton cloth, hung on the wall, 350 g/m²	—	—	0.03	0.04	0.11	0.17	0.24
	Linoleum 5 mm thick on a concrete base	—	5	0.02	0.35	0.05	0.06	0.04
	Rush mats, laid on the wall	—	60	0.56	0.53	0.55	0.64	0.68
	Wool felt	200-300	25	0.09	0.34	0.55	0.66	0.52
	Fiberglass mats	—	40	0.51	0.60	0.76	0.88	0.80
	Perforated plywood ϕ 4 mm, 44 mm from the wall with the space filled with fiberglass	—	40	0.42	0.45	0.47	0.57	0.45
	Aluminum foil	—	0.02	0.3	0.9	0.46	0.35	0.2

(*) Translator's note: This designates Republic Scientific Research Institute of Local Building Materials.

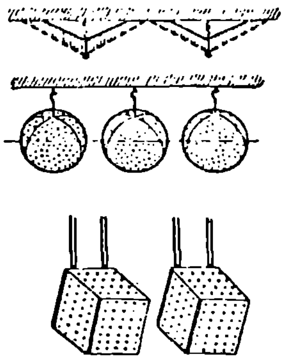


Figure 68. Solid sound absorbers.

sound-absorbing properties, meet fire safety standards, be easy to clean and meet aesthetic requirements in the plant.

In a number of cases, intense noise is created by the operation of pneumatic equipment, compressors, electro-pneumatic hammers, air heaters and ventilators and other processes — in the exhausting compressed air and in drawing it in. Reducing this kind of noise presents great difficulties, therefore, silencers are most often used.

The basic types are active and reactive silencers (acoustic filters). Reactive silencers, based on the principle of the acoustic filter, are complex in structure and are more effective for absorbing low-frequency sounds; active silencers are based on the principle of absorbing sound energy and work more effectively in high frequencies. The selection of the type of silencer is determined by the level and spectrum of the noise, the power of the unit and the resistance of the silencer, convenience of installation and operation. The silencers must be small in size, simple to produce and convenient to operate.

In installing the silencers, it is important that they offer low aerodynamic resistance. Tubular silencers have the least resistance; honeycomb and laminated silencers have great aerodynamic resistance. Silencers with curved channels have especially high resistance. /284

Planning measures will also help reduce noise. Proper design of the relative location of rooms and objects with a consideration of their noisiness is very important in controlling noise.

In developing technical and general plans for factories and ships, noise control must be considered along with technological questions. Noisy factory shops must be concentrated in one or two places within the plant grounds, far from quiet rooms; bushes and leafy trees must be planted around these shops to reduce noise. Medium noisy shops are located beyond this green zone, and further yet, the laboratories, quiet shops and administrative offices. Units which create noise over 130 dB must be located outside the factory and living sector territory, on the

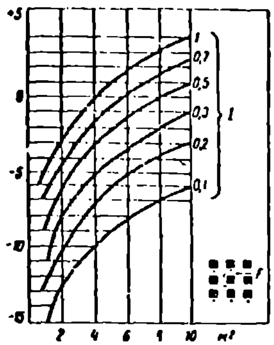


Figure 69. Corrections for the level of sound pressure in work areas. Horizontally — minimum technologically necessary area Fm^2 per unit of equipment, including the passages around it; vertically — correction "b" for permissible level of sound pressure at the work site to obtain a permissible level of sound intensity in dB relative to 10^{-12} V; 1 — sound absorption L_{pr} per 1 m^2 of area F; F: dark squares — equipment, dots — work site.

down wind side in relation to the local prevailing winds, and they must be separated from the edge of the living area by a noise-shielding zone. Units creating noise over 90 dB are placed in insulated rooms, while sources of medium-level noise (less than 90 dB) are concentrated in one part of the shop. The reduction of noise penetrating neighboring rooms should be such that the level of noise in these shops is not increased more than 3 dB.

In projected plans for arranging industrial equipment, in calculating a permissible level of sound pressure at sites, it is necessary that the sound intensity of a unit of production equipment be lower than the sound pressure established by health standards. It is necessary to take into account the sound intensity that is radiated by a unit of production equipment and the minimum technologically necessary area Fm^2 per unit of equipment that must be specified in order not to exceed the maximum permissible level of noise at the work sites. It /285
is necessary to calculate on a special graph what corrections must be made to the level of sound pressure at the work site in relation to the existing sound absorption in the shop and area Fm^2 per unit of equipment (Figure 69).

The distance from noise sources to the residential area is determined by Health standards for projected industrial plants (SN 245-63) (Table 50)(1).

---

(1)See also "Sanitarnyye normy dopustimovo shuma v pomeshcheniyakh..." (Health Standards for Permissible Noise in Factories...), No. 272 - 70.

TABLE 50. MAXIMUM DISTANCES FROM THE ENCLOSING STRUCTURES OF BUILDINGS, LOCATED IN POPULATED AREAS, TO THE SOURCES OF NOISE AND THE MAXIMUM PERMISSIBLE LEVEL OF EMITTED SOUND INTENSITY

Distance from sources of noise to enclosing structures of residential and public buildings located in populated areas, m	Geometric mean frequencies of octave bands, Hz							
	65	125	250	500	1000	2000	4000	8000
	Maximum permissible levels of sound intensity in octave bands (in dB) in relation to 10 - 13 kgm/sec							
50	109	99	91	86	82	80	76	78
100	115	105	97	92	87	86	85	86
200	121	111	104	98	95	94	94	97
300	125	115	107	102	99	98	97	105
400	127	117	110	105	102	102	105	112
500	129	119	112	107	105	105	109	119
700	132	122	115	111	109	110	117	132
1000	135	126	119	115	114	117	127	149

Technological and planning methods and means directed toward reducing noise will considerably help weaken its harmful effect on the workers. Where these measures cannot be implemented or are not effective enough, individual protection must be used.

If the noisy units cannot be soundproofed, for the protection of the workers from the direct emission of noise created by the operating mechanisms, it is necessary to construct acoustic screens made of metal sheets lined with sound absorbing materials. The reduction of noise in places protected by screens is 5 - 8 dB. However, acoustic screens do not protect the workers to the same degree as soundproof remote control booths. They must be well soundproofed, calculated with an allowance for surrounding noises and the sound-absorbing lining of the inner surfaces, reducing the level of noise penetrating the booth.

Soundproof control booths must conform with health requirements in area, ventilation and illumination. /286

It must be kept in mind that lack of proper hermetic sealing around windows, doors and the seals of openings and slots for pipes and conduits to pass through can greatly reduce the sound proofing effect of the enclosing structures. Noise silencers are installed where the air enters the soundproof booths and control posts by the ventilation or air conditioning system or where air is removed in pipes, at the inlet and outlet respectively.

The human organism is protected from excessive sound energy penetrating through the external acoustic meatus by anti-noise devices. Anti-noise devices reduce the noise which reaches the tympanic membrane 10 - 45 dB. The necessary means of protection is selected, depending on the character, level and duration of industrial noise, climatic and microclimatic conditions and the requirements of voice intelligibility in noise conditions.

Anti-noise devices are separated into internal and external and divided into groups: ear plugs (inserts and tampons), half-plugs, earphones and helmets. The effectiveness of sound deadening of individual means of protection is given in Table 51, according to the data of A.I. Voshzhova and V.K. Zakharov (1968).

A government standard has been developed in the USSR which regulates the basic health requirements for this kind of protection, as well as the method of testing the effectiveness of anti-noise devices (GOST-15762-70).

A.I. Vozhzhova feels that with a general level of noise below 100 dB it is completely adequate to use only effective anti-noise devices of the ear plug type, inserts and tampons; at a level from 100 to 125 dB or more, highly-effective helmets are used in addition to internal anti-noise devices.

Recently electronic means of noise protection have begun to be used; these operate on the principle of neutralization of sound vibrations of the same intensity with the opposite phase — an electronic noise absorber and an electronic protector. An electronic absorber consists of a microphone, a phase inverter, and a loud speaker. The electronic protector is placed in a special earphone and creates its own noise, corresponding in loudness, but opposite in phase to the noise which must be cancelled.

We must note that only the systematic use of anti-noise devices from the first entry of the worker into noisy industrial conditions can guarantee protection of the organism from the harmful effect of noise.

The negative effect of noises can also be reduced by shortening the time in contact with it. In drawing up the work schedule, brief breaks must be provided to allow the organ of hearing to recover its function in quiet noiseless conditions. The effectiveness of such rest is indicated in the data of G.L. Navyazhskiy (1948). /288

TABLE 51. THE NOISE-DEADENING EFFECTIVENESS OF INDIVIDUAL MEANS OF NOISE PROTECTION

Individual means of protection	Frequency, Hz: 125	250	500	1000	2000	4000	8000
	Average reduction of noise, dB						
1. Endo-oral means of protection (plugs, tampons, inserts):							
cotton wadding tampons	3	3	3	8	15	15	16
ultrafine fiberglass (UTV) tampons	5	5	10	18	24	30	—
ultrafine fiber tampons FPP-15	8	10	15	22	25	32	—
anti-noise plug of V.I. Voyachek	5	7	8	20	15	24	25
ear plugs designed by A.I. Vozhzhova	8	10	12	15	22	30	—
Dniepropetrovsk plugs of the "Ukraina" factory	10	12	16	18	20	25	—
"Russian diesel" ear plugs	2	2	4	4	6	10	—
Noise filter designed by Aban'kina	7	10	18	20	22	30	—
vacuum antiphones of A.I. Vozhzhova	14	16	17	20	30	36	38
anti-noise devices of P.Ye. Kalmykova	10	14	16	18	24	34	—
wadded-laminated anti-noise device of P.P. Kudryavtsev	20	23	25	32	40	45	—
2. Earphones:							
IGAL earphones with a viscous mass	20	30	25	25	25	55	—
VIAM* earphones with a viscous mass	25	30	30	30	30	55	—
acoustic filters of Polonskiy	—	2	2	5	20	37	33
anti-noise earphones of the PI-2K type	14	15	20	20	30	34	40
anti-noise earphones of the PN-1A or IS type	7	18	23	30	37	33	40
anti-noise earphones of the PI-3 V4Sh type (with a soft mounting)	6	5	10	12	22	25	30
anti-noise earphones of V.S. Baydin	7	11	14	22	35	47	38
AG-2 set	1	1	3	2	10	15	17
AG-4M set	2	2	5	6	21	27	30
G-63 set	22	25	28	30	34	40	42
"Signal" anti-noise devices	15	15	15	15	25	35	30
Kiev earphones without UTV	10	10	25	15	40	25	—
Kiev earphones with UTV	10	15	35	35	45	45	—
PAS-80 earphones	10	8	20	25	28	38	48
MIOT** anti-noise devices of the BV-1 type	—	3	9	16	20	37	—

/287

(Continued on following page.)

(*)Translator's note: This designates All-Union Scientific Research Institute of Aviation Materials.

(**)Translator's note: This designates Moscow Institute of Work Safety.

TABLE 51. THE NOISE-DEADENING EFFECTIVENESS OF INDIVIDUAL MEANS OF NOISE PROTECTION (Continued)

Individual means of protection	Frequency, Hz 125	250	500	1000	2000	4000	8000
	Average reduction of noise, dB						
3. Noise-deadening helmets:							
protective helmet of A.I. Vozhzhova	20	22	30	38	45	45	45
sound-deadening helmet	7	13	17	29	41	50	47
lightened headphone (mesh)	—	16	20	30	32	—	—
IGAL anti-noise device with cotton wadding	10	20	20	20	25	45	55
anti-noise device with V.I. Voyachek compound	20	30	25	25	25	55	—
GAU* anti-noise device	20	20	20	20	40	45	50

This "protection by time", meaning rest from noise in one occupation as well as a combination of occupations, i.e., periodical switching to work unconnected with strong noise, which help rest and restore temporarily disturbed functions of the organism, will prevent the development of permanent damage in the human organism. Low frequency music of low intensity will also encourage more rapid recovery.

In this connection, the studies of G.A. Suvorov are also interesting which compared pulse and stable noise on the basis of the generality of energy of the stimuli, which enabled the author to plan ways to reduce the unfavorable effect of pulse noise on the human organism. These are: 1) taking into consideration, when designing industrial equipment, the fact that the effect of impulse noise on the human organism is reduced with increased pulse time up to 100 m sec. Further increase in the pulse time does not weaken the activity of a pulse noise; the nature of its effect on the organism with t over 100 msec is identical to stable noise of equal intensity; 2) filling in the pause between /289 pulses with background noise, which reduces the severity of its effect on the organism. Comparison of noises of equal mean intensity has shown that the most favorable is that "background- pulse amplitude" combination where the level of the background and the level of pulse noise approaches 0. When the difference is increased to 20 dB or more, the severity of the effect of noise on the organism is intensified; 3) the use of warning light and sound signals. It has been noted that a sound stimulus (a weak force) is most effective if it preceeds the noise

(*)Translator's note: This may designate Main Artillery Directorate.

impulse by 300 m sec, and a light signal (flash of neon tube) by 500 msec;
4) changing the operation of the noisy equipment to other speeds, where the parameters of the noise would be permissible from the point of view of industrial hygiene (200 - 500 per minute range of pulse recurrence frequency).

Organizational measures are very important in protecting the human organism from the harmful effect of noise. They include: devising and establishing maximum permissible noise values, regulated by standard norms, health inspection, as well as conferences and seminars, lectures and talks, the publication of special literature, propagandizing the prevention of noise and effective measures to organize it.

In conclusion, we present medical treatment measures prescribed during polyclinical examination and in stationary conditions.

Medical Treatment of Noise Sickness

Early diagnosis of developing disease is an important aspect of effective medical treatment.

In the presence of disturbances in the central nervous system of a functional nature, in the cardio-vascular system as well as in a number of other organs and systems of man, observed as the result of the effect of noise, it is necessary to conduct complex therapy.

Usually, general strengthening treatment is prescribed, regular nourishment, a strict sleep regime, compulsory daily airing for 1 - 2 hours. Prescribed are bromides, elenium, trioxazine, amicyl and sometimes soporifics. The use of glutamic acid and rutin is recommended.

Physiotherapeutic treatment is widely used — galvanization according to the method of Shcherbak, d'arsonvalism, static electricity, as well as salt-pine baths, sulfur baths, hand and foot baths before sleep.

With pronounced ahyposthenic syndrome, besides the general strengthening treatment, stimulating preparations must be prescribed (limonene, gentian, securinine, /290
caffeine, etc.). The use of vitamin therapy is widelv recommended for the successful treatment of noise sickness. Vitamin C is given for its general strengthening

effect, and a complex of vitamins B_1, B_6 and B_{12} which favorably affects the functional state of the central nervous system as well as nephritis of the auditory nerve. Vitamins A and E are also recommended, which have a positive effect on circulation and increase oxidizing processes in the organism.

Some clinics have recently started to use the radio-acoustic method of treating nephritis of the auditory nerve. Radio-waves used for the treatment are modulated by frequencies of sonic and ultrasonic ranges, which affect the nerve elements of the auditory analysor. As the authors note, this method has no side effects and does not cause irritation. At the moment this procedure is conducted, the patients feel only a slight sensation of heat (manfredi Angelo, Bombelli, Uga, 1963).

In those cases when the patients complain of intra-oral noise, it is recommended that sedatives be prescribed (bromides, luminal); favorable results of treatment with novocaine have also been described.

In case of increased arterial pressure, besides the above mentioned measures, a rational diet is recommended, with restriction of food high in cholesterol and animal fats, smoking, and alcohol are proscribed and other irritating factors eliminated. In pronounced cases of increased arterial pressure, sedatives are used in various combinations (bromine, luminal, valerian, etc.), as well as neuroplegic substances, among which preparations of Rauwolfia were very important — reserpine etc., ganglion blocks (pentamine, dicholine, etc.) and sympatholytics (apressine etc.).

In the presence of hypotonia in noise sickness patients, substances which increase vascular tone are recommended (phenamine, Chinese limonine, pantocrine, etc.).

In cases of functional disturbances of the activity of the stomach, besides these general measures to strengthen the nervous system, a sparing diet, and a vitamin complex as prescribed by S.M. Ryssa is recommended.

One of the important stages in the whole system of medical treatment measures of noise sickness patients is firmly establishing the results of treatment in health resort conditions (Ye.Ts. Andreyeva-Galanina, S.V. Alekseyev, 1968).

A.I. Nesterov, considering the complex effect of health resort treatment on the organism, attaches special importance to environmental factors, — getting /291 away from ordinary every-day social surroundings and changing to a new medium, in an environment of rest, quiet and confidence in the success of the treatment, which in turn has a positive effect on the functional state of the nervous system as well as other organs and systems of the person. The effect of natural factors — air, sun, the sea, beautiful landscape, changing the usual regime to excursions, walks, and physical exercise will, in his opinion, lead the organism to a state of "physiological comfort."

At the present time, great importance is attached to the treatment of noise sickness in health resort conditions at the Nal'chik-Dolinsk resort, where scientific and practical work is being carried out in a specialized section of the "Elbrus" sanatorium by doctors, together with workers in the department of Industrial Health of the Leningrad Medical Institute of Health and Hygiene, on determining the effectiveness and refining methods of health resort treatment.

Belorechenskiye and Dolinskiye mineral baths are being used successfully in the complex treatment administered by the doctors of the sanatorium. The favorable reactions of patients to the effect of Belorechenskiye mineral baths is connected with the increased positive tone of the cortex, helping to normalize cortico-subcortical relations, improving the functional state of the cardio-vascular system because of the weak mineralization ($M = 0.4\ g/l$ and the high nitrogen gas content ($49.1\ cm^3/l$). Belorechenskiye baths do not usually cause a feeling of fatigue in the patients and are easily tolerated.

Dolinskiye mineral baths increase weakened active inhibition, quiet the stimulatory process, reduce arterial pressure; single baths affect the tone of small arteries. Their positive effect in the treatment of noise sickness patients is probably connected with the large amount of bromine ($0.36\ mg/l$).

Concluding this section, we must note that little data on the treatment of noise sickness has yet been accumulated, and specialists are faced with the great tasks of refining indices, developing differential treatment complexes, and determining the effectiveness of the treatment measures being carried out.

REFERENCES

1. Aleksandrov, A.I., G.M. Komarovich, Z.P. Lebedeva and R.A. Loyt. Vestnik otorinolaringologov., Vol. 3, 1963, p. 15.

2. Alekseyev, S.V. In the collection: Trudy LSGMI (Works of the Leningrad Medical Institute of Health and Hygiene). Leningrad, Vol. 82, 1964.

3. Alekseyev, S.V. O deystvii stabil'nogo shuma na nekotoryye fiziologichiskiye funktsii (On the Effect of Stable Noise on Certain Physiological Functions). Author's abstract of dissertation, Leningrad, 1965.

4. Alekseyev, S.V. Gig. truda, Vol. 6, 1968, p. 27.

5. Alekseyev, S.V. and Kh.A. Getsel'. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ihk vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on the Problem: "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and the Prevention of a Harmful Effect"). Leningrad, Vol. 5, 1968.

6. Alekseyev, S.V. and G.A. Suvorov. In the book: Metodicheskiye voprosy izlucheniya deystviya shuma na organizm (Methodological Problems of Studying the Effect of Noise on the Organism). Theses of reports. Moscow, Vol. 18, 1963.

7. Alekseyev, S.V. and G.A. Suvorov. Gig. Truda, Vol. 6, 1965, p. 8; Vol. 5, 1967, p. 35.

8. Alekseyev, S.V., G.A. Suvorov and A.M. Likhnitskiy. In the book: Bor'ba s shumami i vibratsiyami (Controlling Noises and Vibrations). Moscow, Vol. 5, 1966.

9. Alekseyeva, M.S., V.I. Yelkina and V.K. Fedorova. Zhurn. vyssh. nerv. deyat., Vol. 14, No. 1, 1964, p. 110.

10. Aliyeva, R.Kh. Gigienicheskaya otsenka shuma pri gidravlicheskom razryve plastov v nefteobrabatyvayushchey promyshlennosti (Hygiene Evaluation of Noise in the Hydraulic Breaking of Strata in the Petroleum Industry). Author's abstract of dissertation, Baku, 1968.

11. Al'pern, L.L., D.Yu. Belevskiy and I.S. Ivatsevich. Gig. i san., Vol. 10, 1962, p. 69.

12. Al'tman, Ya.A. In the collection: Tezisy dokladov Vseross. konf. po voprosam tugoukhosti (Theses of Reports to the All-Russian Conference on Deafness). Leningrad, Vol. 12, 1960.

13. At'tman, Ya.A. Elektricheskiye otvety razlichnykh otdelov slukhovoy sistemy v usloviyakh dlitel'nogo ritmicheskogo zvukovogo razdrazheniya (Electric Responses of Various Sections of the Auditory System in Conditions of Prolonged Rhythmical Sonic Stimulation). Author's abstract of dissertation, Moscow, 1961.

14. Andreyev, L.A. Fiziologiya organov chuvstv (Physiology of Sense Organs). Moscow, 1941.

15. Andreyeva-Galanina, Ye.Ts. Gig. i san., Vol. 4, 1959, p. 52.

16. Andreyeva-Galanina, Ye.Ts. Vnedreniye novoy tekhniki v proizvodstvo i zadachi gigiyeny truda (The Introduction of New Techniques into Industry and Problems of Industrial Hygiene). Moscow, 1964.

17. Andreyeva-Galanina, Ye.Ts. In the book: Rukovodstvo po gigiyene truda (Handbook of Industrial Hygiene), Vol. 1, Shum (Noise). Moscow, Chapt. IV, 1965.

18. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev and G.A. Suvorov. Gig i san., Vol. 1, 1965, p. 44.

19. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev, G.A. Suvorov and A.V. Kadyskin. In the book: Bor'ba s shumami i vibratsiyami (Controlling Noises and Vibrations). Moscow, Vol. 12, 1966.

20. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev and A.V. Kadyskin. Gig. truda, Vol. 10, 1967, p. 14.

21. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev, A.V. Kadyskin and G.A. Suvorov. In the collection: Mater. yubileynoy nauchnoy sessii LSGMI, posvyashchennoy 50-letiyu Velikoy Oktyabr'skoy sotsialisticheskoy revolyutsii (Material of the Anniversary Scientific Conference of the LSGMI, Dedicated to the 50th Anniversary of the Great October Socialistic Revolution). Leningrad, Vol. 29, 1967.

22. Andreyeva-Galanina, Ye.Ts. and S.V. Alekseyev. In the collection: Mater, konf. po probleme "Sanitorno-kurortnoye lecheniye vibratsionnoy bolezni" (Material of the Conference on "Health Resort Treatment of Vibration Sickness"). Nal'chik, Vol. 3, 1968.

23. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev and A.V. Kadyskin. In the collection: Mater. VI Vsesoyuzn. akustich. konf. (Material of the VI All-Union Acoustics Conference). Moscow, 1968, p. 17.

24. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev, G.A. Suvorov and A.V. Kadyskin. /293
Vestn. AMN SSSR, Vol. 3, 1968, p. 11.

25. Andreyeva-Galanina, Ye.Ts. and V.G. Artamonova. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume u ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on "The Current State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Prevention of a Harmful Effect"). Leningrad, 1968.

26. Andreyeva-Galanina, Ye.Ts., A.V. Kadyskin and O.M. Rukavisova. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystiviya". (Material of the Scientific Conference on "The Current State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Prevention of a Harmful Effect"). Leningrad, Vol. 13, 1968.

27. Andreyeva-Galanina, Ye.Ts., S.V. Alekseyev, G.A. Suvorov and A.V. Kadyskin. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizgod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on "The Current State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and the Prevention of a Harmful Effect"). Leningrad, Vol. 6, 1968.

28. Andreyeva-Galanina, Ye.Ts., G.A. Suvorov and A.M. Likhnitskiy. Gig. i san., Vol. 8, 1968, p. 24.

29. Andreyeva-Galanina, Ye.Ts. and G.A. Suvorov. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on: "The Current State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and the Prevention of a Harmful Effect"). Leningrad, Vol. 16, 1968.

30. Andreyeva-Galanina, Ye.Ts. et al. Gig. i san., Vol. 5, 1969, p. 26.

31. Andryukin, A.A. Znacheniye shuma v razvitii gipertonii (The Importance of Noise in the Development of Hypertonia). Author's abstract of dissertation, Moscow, 1961a.

32. Andryukin, A.A. Gig truda, Vol. 12, 1961b, p. 11.

33. Anichkov, S.V. Yezhegodnik in-ta eksp. med., Leningrad, Vol. 3, 1958, p. 153.

34. Anichin, V.F. Zhurn. ushn., nos. i gorl. bol., Vol. 5, 1965, p. 46.

35. Anichin, V.F. In the collection: Trudy LNII po boleznyam ukha, gorla, nosa i rechi (Works of the Leningrad Scientific Research Institute on Diseases of the Ear, Throat, Nose and Voice). Leningrad, Vol. 14, 1966a, p. 245.

36. Anichin, V.F. Gistokhimicheskiye i gistologicheskiye izmeneniya v kortiyevom organe pri vozdeystvii stabil'nykh i preryvistykh shumov (Histochemical and Histological Changes in the Organ of Corti under the Effect of Stable and Discontinuous Noises). Author's abstract of dissertation. Leningrad, 1966b.

37. Anichin, V.F. Vestn. otorinolar., Vol. 3, 1968, p. 32.

38. Anokhin, P.K. Vnutrenneye tormozheniye kak problema fiziologii(Internal Inhibition as a Physiological Problem). Moscow, 1958.

39. Anokhin, P.K. Zhurn. vyssh. nervn. deyat., Vol. 12, No. 3, 1962, p. 379.

40. Apostolov, Todorov. Slukhovaya adaptatsiya pri professionalen podbor na rabotnitsi za proizvodstva svurzani s mnogo shum (Auditory Adaptation in Occupational Selection of Workers for a Factory Producing a Great Deal of Noise). Author's abstract of dissertation, Sofia, 1968.

41. Arkad'yevskiy, A.A. Biofizika, Vol. 4, 1956, p. 2.

42. Arkad'yevskiy, A.A. Gig i san., Vol. 9, 1960, p. 21; Vol. 2, 1962a, p. 25; Vol. 10, 1962b, p. 25.

43. Arkad'yevskiy, A.A. Opyt bor'by s shumom i vibratsiyey v promyshlennosti (Testing of Noise and Vibration Control in Industry). Collection I, Moscow, Vol. 8, 1963.

44. Aspisov, N.M. Vestn. otorinolar., Vol. 4, 1948, p. 10.

45. Akhmatov, A.S. Zh. prikl. fiziki, Vol. 2, 1925, p. 51.

46. Babadzhanyan, M.G. In the collection: Mater. k fiziologicheskomu obosnovaniyu trudovykh protsessov (Material for the Physiological Basis of Work Processes). Moscow, 1960.

47. Basamygina, L.Ya. Sostoyaniye sosudistoy sistemy shakhterov, rabotayushchikh s pnevmaticheskimi instrumentami (The State of the Vascular System of Miners Working with Pneumatic Tools). Author's abstract of dissertation, Donetsk, 1963.

48. Bakhrakh, D.I. and B.Ye. Sheyvekhman. In the collection: Problemy fiziologicheskoy akustiki (Problems of Physiological Acoustics, I.). Moscow, Vol. 166. 1949.

49. Belikov, P.N. Zh. prikl. fiziki, Vol. 2, 1925, p. 47; Vol. 5, 1928, supplement, Vol. 127.

50. Benyumov, I.A. Vrach. delo., Vol. 4, 1963.

51. Bekhtereva, N.P. In the collection: Problemy sovremennoy neyrofiziologii (Problems of Modern Neurophysiology). Moscow-Leningrad, Vol. 100, 1965.

52. Bekhtereva, N.P. In the collection: Glubokiye struktury golovnogo mozga cheloveka v norme i patologii (Deep Structures of the Normal Human Brain and in Pathology). Moscow-Leningrad, Vol. 18, 1966.

53. Bekhtereva, N.P. Fiziologiya i patofiziologiya glubokikh struktur mozga cheloveka (Physiology and Pathophysiology of Deep Structures of the Human Brain). Moscow-Leningrad, 1967.

54. Bekhtereva, N.P., K.V. Grachev, R. Gombi and T.S. Stepanova. In the collection: /294
Mater. IV Vsesoyuzn. elektrofiziol. konf. (Material of the IV All-Union Electrophysiology Conference). Rostov on Don., Vol. 50, 1963.

55. Bekhtereva, N.P., A.V. Bondarchuk and V.V. Zontov. Bolezn' Reyno (Raynaud's Disease). Leningrad, 1965.

56. Birinskiy, V.M. Gigiyenicheskaya otsenka usloviy truda na magistral'nom dizel'nom lokomotive (Health Evaluation of Working Conditions on a Main Line Diesel Locomotive). Author's abstract of dissertation, Leningrad, 1966.

57. Bobin, Ye.V. Bor'ba s proizvodstvennym shumom na zheleznodorozhnom transporte (Controlling Industrial Noise in Railway Transport). Moscow, 1964.

58. Bogdelevskiy, V.D. Krivaya myshechnoy ustalosti u cheloveka pod vliyaniyem raznykh usloviy (Curve of Muscular Fatigue in Man Under the Effect of Various Conditions). Dissertation, St. Petersburg, 1891.

59. Borodkin, Yu.S. Antifeiny (Antiphones). Leningrad, 1967.

60. Borshchevskiy, I.Ya. and E.V. Lapayev. Voen. -med. zhurn., Vol. 2, 1965, p. 64.

61. Brodal, A. Retikulyarnaya formatsiya mozgovogo stvola (Reticular Formation of the Brain Stem). Moscow, 1960.

62. Bruzhes, A.P. and A.A. Arkad'evskiy. Biofizika (Biophysics). Vol. 1, 1956, p. 1.

63. Buresh, Ya., M. Petran' and I. Zakhar. Elektrofiziologicheskiye metody issledovaniya (Electrophysical Research Methods). Moscow, 1962.

64. Burlova, L.Ya. Cited by Ye.Ts. Andreyeva-Galanina, 1965.

65. Burlova, L.Ya., A.F. Lebedeva and A.V. Tarasova. Gigiyena truda na predpriyatiyakh tekstil'noy promyshlennosti (Industrial Hygiene in Textile Factories). Moscow, 1963.

66. Bykhovskiy, A.V. K voprosu o neadekvatnom vliyanii shuma (On the Question of the Inadequate Effect of Noise). Author's abstract of dissertation, Chelyabinsk, 1948.

67. Vasil'yev, A.I. Izbrannyye voprosy otorinolaringologii (Selected Questions of Otorhinolaryngology). Moscow, Vol. 137, 1956.

68. Vasilevskiy, N.N. Neyronal'nyye mekhanismy kory bol'shikh polushariy (Neuron Mechanisms of the Cortex of the Large Hemispheres). Leningrad, 1968.

69. Vvedenskiy, N.Ye. (1920). Collected works, LGU, L., Vol. 4, 1953, p. 159.

70. Vedyayev, F.P. Podkorkovyye mekhanizmy slozhnykh dvigatel'nykh refleksov (Subcortical Mechanisms of Complex Motor Reflexes). Leningrad, 1965.

71. Verzilova, O.V., V.F. Mostun, N.I. Mostun and G.N. Erdman. In the collection: Voprosy fiziologii i patologii nervnoy sistemy (Questions of the Physiology and Pathology of the Nervous System). Moscow, Vol. 6, 1962, p. 18.

72. Vinnik, S.A. Akusticheskoye porazheniye organa slukha (Acoustic Damage to the Organ of Hearing). Gorky, 1940.

73. Vinnikov, Ya.A. and L.K. Titova. Kortiyev Organ (The Organ of Corti). Moscow-Leningrad, 1961.

74. Vishnevskaya, S.S. and S.I. Gorshkov. Gig. truda., Vol. 11, 1960a, p. 18.

75. Vishnevskaya, S.S. and S.I. Gorshkov. In the book: Vibratsiya i shum (Vibration and Noise). Moscow, Vol. 86, 1960b.

76. Vozhzhova, A.I. and I.A. Sapov. Gig. truda, Vol. 5, 1960, p. 36.

77. Vozhzhova, A.I. and V.K. Zakharov. Zashchita ot shuma i vibratsii na sovremennykh sredstvakh transporta (Protection from Noise and Vibration in Modern Means of Transportation). Leningrad, 1968.

78. Volkov, A.M. Gig. i san., Vol. 1, 1958a, p. 33.

79. Volkov, A.M. Gig. truda, Vol. 3, 1958b, p. 9.

80. Volkov, A.M. Gig. i san., Vol. 1, 1961, p. 33.

81. Volkov, A.M. In the collection: Mater. IV nauchn. konf. po fiziologii truda, posvyashch. Pamnyati A.A. Ukhtomskogo (Material of the IV Scientific Conference on the Physiology of work, Dedicated to the Memory of A.A. Ukhtomskiy). Leningrad, Vol. 67, 1963a.

82. Volkov, A.M. Gig. truda, Vol. 11, 1963b.

83. Volkov, A.M., M.G. Babadzhanyan and Ye.I. Kostina. Inf. byull. NII gigiyeny im. Erismana, Vol. 6 - 7, 1957, p. 52.

84. Volkov, A.M. and T.L. Sosnova. Metod. voprosy izucheniya deystviya shuma na organizm (Methodological Questions in the Study of the Effect of Noise on the Organism). Moscow, 1963.

85. Vokokhov, A.A. and G.V. Gershuni. Fiziol. zhurn. SSSR, Vol. 18, 1935, p. 523.

86. Vorontsov, V.N. In the collection: Mater. XXVIII otchetnoy nauchn. konf. aspirantov i klinicheskikh ordinatorov LSGMI (Material of the 28th Scientific Conference of Graduate Students and Clinical Interns of LSGMI). Leningrad, Vol. 15, 1968.

87. Voyachek, V.I. Zhurn. ushn., nos. i gorl. bol., Vol. 3, No. 4, 1927, p. 12.

88. Galakhov, I.I. and A.I. Kachevskaya. In the book: Bor'ba s shumom i deystviye shuma na organizm (Controlling Noise and the Effect of Noise on the Organism), 2. Leningrad, Vol. 47, 1958.

89. Gershuni, G.V. In the book: Sovremennyye problemy elektrofiziologicheskikh issledovaniy nervnoy sistemy (Current Problems of Electrophysiological Research on the Nervous System). Moscow, 1964.

90. Gershuni, G.V. Zhurn. vyssh. nervn. deyat., Vol. 15, No. 2, 1965, p. 260.

91. Gershuni, G.V. and N.V. Zaboyeva. Fiziol. zhurn. SSSR, Vol. 48, 1962, p. 117.

92. Gol'dburt, S.N. Arkh. biol. nauk., LKh, Vol. 1, 1940, p. 24.

93. Gol'dburt, S.N. Neyrodinamika slukhovoy sistemy cheloveka (Neurodynamics of the Auditory System of Man). Leningrad, 1964. /295

94. Gol'dman. E.I. Gig. i san., Vol. 6, 1962, p. 65.

95. Gombi, R. Bioelektricheskiye effekty svetovykh i zvukovykh razdrazheniy v glubokikh otdelakh mozga cheloveka (Bioelectric Effects of Light and Sound Stimuli in the Deep Sections of the Human Brain). Author's abstract of dissertation. Leningrad, 1964.

96. Grinberg, G.I. Vestn. otorinolar., Vol. 14, 1952; Vol. 1, 1957, p. 21.

97. Grinshteyn, A.M. Puti tsentral'noy nervnoy sistemy (Pathways of the Central Nervous System). Moscow, 1946.

98. Grobshteyn, S.S. and A.V. Kugaro. Russ. otolaringol., Vol. 6, 1931, p. 429.

99. Gusel'nikov, V.I. and A.Ya. Supin. Ritmicheskaya aktivnost' golovnogo mozga (Rhythmical Activity of the Brain). Moscow, 1968.

100. Gusel'nikova, K.G. Izucheniye nekotorykh mekhanizmov epileptiformnogo pripadka u krys metodom elektroentsefalografii (A Study of Several Mechanisms of Epileptiform Convulsion in Rats by the Electroencephalographic Method). Author's abstract of dissertation, Moscow, 1958.

101. Davidenkov, S.N. In the book: Rukovodstvo po nevropatologii (Handbook on Neuropathology). Moscow, Vol. 6, 1960, p. 302.

102. Denisenko, P.P. Tsentral'nyye kholinolitiki (Central Cholinolytics). Moscow, 1965.

103. Dimov, I., K. Kiryakov and P. Machev. Khirurgiya (Surgery). (Sofia), Vol. 13, No. 10, 1960, p. 863.

104. Dobrogayev, S.M. Konspekt kursov fiziologii rechi, patofiziologii rechi i logoterapii (Synopsis of Courses in the Physiology of Speech, the Pathophysiology of Speech and Logotherapy). Leningrad, 1934.

105. Dombrovskiy, R.V. and R.T. Kalust'yan. Akust. zhurn., Vol. 3, 1962, p. 364.

106. Drever, D.N. Psikhologiya truda (Psychology of Work). Moscow-Leningrad, 1926.

107. Drogichina, E.A. and L.A. Kozlov. In the book: Professional'nye bolezni (Occupational Diseases). Moscow, Vol. 128, 1957.

108. Drogichina, E.A. and N.B. Metlina. Gig. truda, Vol. 7, 1962.

109. Drogichina, E.A., L.Ye. Milkov and D.A. Ginzburg. Gig. i san., Vol. 2, 1965, p. 29.

110. Dumkina, G.Z. Nekotoryye kliniko-fiziol. issledovaniya u rabochikh, podvergavshikhsya deystviyu stabil'nogo shuma (Several Clinical-Physiological Studies of Workers Subjected to the Effect of Stable Noise). Author's abstract of Dissertation, Leningrad, 1965.

111. Durinyan, R.A. Tsentral'naya struktura afferentnykh sistem (Central Structure of Afferent Systems). Leningrad, 1965.

112. Yevdokimova, I.B., I.K. Razumov and L.N. Shkarinov. In the collection: Mater. nauchn. sessi po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on: "The Current State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and the Prevention of a Harmful Effect"). Leningrad, Vol. 12, 1968.

113. Yenin, I.P. Vliyaniye obshchey vibratsii vysokikh parametrov i shuma na organ slukha i vestibulyarnyy apparat (The Effect of General Vibration of High Parameters and Noise on the Organ of Hearing and the Vestibular Apparatus). Author's abstract of dissertation, Leningrad, 1965.

114. Yermolayev, V.G. In the collection: Trudy, posvyashshennyye 35-letney deyatel'nosti V.N. Voyacheka (Works Dedicated to the 35th Anniversary of the Work of V.N. Voyachek), Vol. 1. Leningrad, Vol. 350, 1936.

115. Yerokhin, V.N. Kombinirovannoye deystviye shirokopolosnogo shuma i obshchey vibratsii na organ slukha i vestibulyarnyy apparat (The Combined Effect of Wide Band Noise and General Vibration on the Organ of Hearing and the Vestibular Apparatus). Author's abstract of dissertation, Leningrad, 1969.

116. Zaritskaya, L.A. and D.P. Kachalay. In the collection: Mater. 3-y Respubl. konf. terapevtov. (Material of the 3rd Republic Conference of Therapists). Baku, 1965.

117. Zasosov, R.A. O vozdeystvii i detonatsii sverkhmoshchnykh zvukov, ul'trazvukov i vibratsii na ushnoy apparat i organizm (On the Effect and Detonation of Ultrahigh Sounds, Ultrasonics and Vibration on the Ear and the Organism). Leningrad, 1945.

118. Zakher, A.V. In the collection: Trudy Len. in-ta po izucheniyu prof. zabolevaniy (Works of the Leningrad Institute for the Study of Occupational Diseases). Leningrad, Vol. 1, 1926, p. 227.

119. Zeygel'shefer, B.D. O kombinirovannom vozdeystvii razlichnykh parametrov stabil'nogo shuma i okisi ugleroda na organizm (On the Combined Effect of Various Parameters of Stable Noise and Carbon Monoxide on the Organism). Author's abstract of dissertation, Leningrad, 1968.

120. Zelikina, T.I. and V.Ye. Shungskaya. In the book: Bor'ba s shumami i deystviye shuma na organizm (Controlling Noises and the Effect of Noise on the Organism). Leningrad, Vol. 3, 1958, p. 22.

121. Zil'ber, D.A. Vrach. delo., Vol. 5, 1949, p. 445.

122. Zuyev, G.I. Materialy k voprosu o vliyanii kompleksnogo vozdeystviya vysokochastotnogo shuma i vibratsii na nekotoryye funktsii organizma cheloveka v usloviyakh proizvodstva (Material on the Question of the Complex Effect of High-Frequency Noise and Vibration on Several Functions of the Human Organism in Industrial Conditions). Author's abstract of dissertation, Leningrad, 1960.

123. Ivatsevich, I.S. In the collection: Metod. voprosy izucheniya deystviya shuma no organizm (Methodological Questions in the Study of the Effect of Noise on the Organism). Moscow, Vol. 93, 1963.

124. Il'yuchenok, R.Yu. Neyrogumoral'nyye mekhanizmy retikulyarnoy formatsii stvola mozga (Neuro-Humoral Mechanisms of the Reticular Formation of the Brain Stem). Moscow, 1965. /296

125. Il'yashchuk, Yu. M. Izmereniya i normirovaniye porizvodstvennogo shuma (Measurement and Standardization of Industrial Noise). Moscow, 1964.

126. Kadyskin, A.V. In the collection: Mater. III nauchno-prakt. konf. posvyashch. vibratsionnoy i shumovoy bolezni i ikh profilaktike (Material of the 3rd Scientific and Practical Conference on Vibration and Noise Sickness and Their Prevention). Donetsk., Vol. 27, 1966a.

127. Kadyskin, A.V. In the collection: Mater XXVI otchetnoy nauchn. konf. aspirantov i klinicheskikh ordinatorov LSGMI (Material of the 26th Scientific Conference of Graduate Students and Clinical Interns of LSTMI). Leningrad, 1966b.

128. Kadyskin, A.V. In the book: Bor'ba s shumami i vibratsiaymi (Combatting Noises and Vibrations). Moscow, Vol. 19, 1966a.

129. Kadyskin, A.V. In the collection: Elektrofiziologiya tsentral'noy nervnoy systemy. V Vsesoyuzn. konf. po elektrofiziologii tsentral'noy nervnoy sistemy (Electrophysiology of the Central Nervous System. 5th All-Union Conference on ElectroPhysiology of the Central Nervous System). Tbilisi, Vol. 139, 1966g.

130. Kadyskin, A.V. In the collection: Mater. mezhkafedral'mykh nauchnykh konf. gig. kafedr LSGMI (Dobroslavinskie chteniya) [Material of the Interdepartmental Scientific Conference of the Hygiene Department of LSGMI (Welcoming Address)]. Leningrad, Vol. 2, 1967a.

131. Kadyskin, A.V. In the collection: Trudy 2 LOR s"yezda RSFSR (Works of the 2nd ENT Conference RSFSR). Moscow, Vol. 39, 1967b.

132. Kadyskin, A.V. O vliyanii shirokopolosnykh stabil'nykh shumov na funktsional'noye sostoyaniye razlichnykh otdelov tsentral'noy nervnoy sistemy (On the Effect of Wide Band Stable Noises on Various Sections of the Central Nervous System). Author's abstract of dissertation, Leningrad, 1967b.

133. Kadyskin, A.V. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo seystviya" (Material of the Scientific Conference on: "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Preventing of a Harmful Effect"). Leningrad, Vol. 60, 1968.

134. Kachalay, D.P. and P.D. Volokh. Vrach. delo., Vol. 5, 1964.

135. Kekcheyev, K.Kh. and Ye.P. Ostrovskiy. Dokl. AN SSSR, Vol. 36, 1941, p. 4.

136. Knryakov, K. Zhurn. vyssh. nervn. deyat., Vol. 14, No. 3, 1964, p. 412.

137. Kogan, A.B. Elektrofiziologicheskoye issledovaniye tsentral'nykh mekhanizmov nekotorykh slozhnykh refleksov (Electrophysiological Study of the Central Mechanisms of Several Complex Reflexes). Moscow, 1949.

138. Kozhevnikov, V.A. and A.I. Maruseva. Izv AN SSSR, seriya biol. (Biology Series), Vol. 5, 1949, p. 560.

139. Kozlov, L.A. In sb. rabot profession. patologii organa slukha (Collection of Works on Occupational Pathology of the Organ of Hearing). Moscow, Vol. 25, 1929, p. 91.

140. Komendantov, G.L. Yubileynyy otolaringologicheskiy sbornik, posvyashchennyy pamyati A.I. Zimina (Anniversary Otolaryngological Collection, Dedicated to the Memory of A.I. Zimin). Novosibirsk, Vol. 61, 1933.

141. Komendantov, L.Ye. In the book: Voprosy fiziologii i patologii ukha (Questions on the Physiology and Pathology of the Ear). Leningrad, Vol. 9, 1937.

142. Konikov, A.A. Byull. eksper. biol., Vol. 4, 1937, p. 4.

143. Kopylov, A.G. In the collection: Voprosy teorii i praktiki elektroentsefalografii (Questions on the Theory and Practice of Electroencephalography). Leningrad, Vol. 96, 1966.

144. Koryukayev, Yu.S. Rukovodyachshiye ukazaniya po ozdorovleniyu usloviy truda pri rabote s pnevmaticheskim ruchnym instrumentom v sudostroyenii. TSNII tekhnologii sudostroyeniya (Directions for Improving the Health Conditions of Work with Pneumatic Equipment in Ship Building. Central Scientific Research Institute of Ship Building Technology). Leningrad, 1964.

145. Koryukayev, Yu.S. Proizvodstv. sanitariya v sudostroyenii(Industrial Health in Ship Building). Leningrad, 1969.

146. Kostenetskaya, N.A. Uslovno-reflektornaya regulyatsiya tonusa kory golovnogo mozga (Condition Reflex Regulation of the Tone of the Cerebral Cortex). Leningrad, 1965.

147. Kostyuk, P.G. In the collection: Mater. po voprosam elektrofiziologii tsentral'noy nervnoy sistemy (Material on the Electrophysiology of the Central Nervous System). Moscow, Vol. 66, 1958.

148. Kravkov, S.V. Vzaimodeystviye organov chuvstv (The Interaction of Sense Organs). Moscow-Leningrad, 1948.

149. Kratin, Yu.G. Elektricheskiye reaktsii mozga na tormoznyye signaly (Electrical Reaction of the Brain to Inhibitory Signals). Leningrad, 1967.

150. Kratin, Yu.G., N.P. Bekhtereva, V.I. Gusel'nikov, V.A. Kozhevnikov, V.T. Senichenkov and V.V. Usov. Tekhnika i motodiki elektroentsefalografii (Techniques and Methods of Electroencephalography). Moscow-Leningrad, 1963.

151. Krauz, V.A. Sravnitel'naya kharakteristika deystviya ryada tsentral'nykh M- i N-kholinolitikov na razlichnye struktury i sistemy golovnogo mozga (Comparative Characteristics of the Effect of a Number of Central M- and N-Cholinolytics in Various Structures and Systems of the Brain). Author's abstract of dissertation, Leningrad, 1968.

152. Krivitskaya, G.N. Deystviye sil'novyo zvuka na mozg (The Effect of an Intense Sound on the Brain). Moscow, 1964.

153. Krivoglaz, B.A., A.A. Model', V.G. Boyko, L.A. Zaritskaya and D.P. Kachalay. In the book: Gigiyena truda (Industrial Hygiene). Kiev, Vol. 195, 1967.

154. Krushinskiy, L.V. and L.N. Molodkina. Dokl. AN SSSR, Vol. 66, No. 2, 1949, p. 289.

155. Krushinskiy, L.V. and L.N. Molodkina. Usp. sovr. biol., Vol. 3, 1957.

156. Krushinskiy, L.V., L.N. Molodkina and D.A. Fless. Zhurn. obshchey biol., Vol. 11, No. 2, 1950, p. 104.

157. Krylova, N.N. In the collection: Trudy LSGMI (Works of the LSGMI). Leningrad, Vol. 231, 1958.

158. Kublanova, P.S. and N.V. Pomerantseva. Zhurn. ushn., nos. i gorl. bol., Vol. 5, 1967, p. 56.

159. Lebedeva, A.F. and A.I. Vozhzhova. In the book: Issledovaniya po gigiyene truda i prof. patologii (Studies of Industrial Hygiene and Occupational Pathology). Leningrad, Vol. 75, 1963.

160. Levin, V.M. and E.S. Rutenburg. Vrachebnaya professional'naya konsul'tatsiya podrostkov (Medical Occupational Consultations of Adolescents). Leningrad, 1960.

161. Livanov, M.N. In the book: Nekotoryye voprosy sovremennoy elektroentsefalografii (Several Questions of Modern Electroencephalography). Moscow-Leningrad, 1960.

162. Lipovoy, V.V. Gig. truda, Vol. 2, 1969, p. 19.

163. Lozanov, N.N. and S.F. Gamayunov. Vestn. rinolar., Vol. 3 - 4, 1929, p. 324.

164. Lyubomudrov, V.Ye., B.N. Onopko and L.Ya. Basamygina. Vibratsionnoshumovaya bolezn' (Vibration-Noise Sickness). Kiev, 1968.

165. Mayorchik, V.Ye. Klinicheskaya elektrokortikografiya (Clinical Electrocorticography). Moscow, 1964.

166. Makarov, P.P. In the collection: Trudy 1-y konf. po fiziologicheskoy optike (Works of the 1st Conference on Physiological Optics). Leningrad, 1936.

167. Mashkovskiy, M.D. Med. prom. SSSR, Vol. 4, 1955, p. 32.

168. Mashkovskiy, M.D. In the collection: Khimiya i meditsina. Moscow, Vol. 5, 1956, p. 5.

169. Mashkovskiy, M.D. Lekarstvennyye sredstva (Medicines). Moscow, 1960.

170. Medovoy, A.M. Vestn. sov. otorinilar., Vol. 1, 1932, p. 98.

171. Milkov, L.Ye. Gig. i san., Vol. 9, 1960, p. 26.

172. Milkov, L.Ye. Vliyaniye intensivnogo proizvodstvennogo shuma na funktsional'noye sostoyaniye nervnoy sistemy (The Effect of Intense Industrial Noise on the Functional State of the Nervous Ssytem). Author's abstract of dissertation, Moscow, 1963a.

173. Milkov, L.Ye. Gig. truda, Vol. 4, 1963b, p. 38.

174. Mikhayluts, A.P. Gigiyenicheskaya kharakteristika usloviy truda v derevoobrabatyvayushchey promyshlennosti (Hygiene Characteristics of Working Conditions in the Wood Processing Industry). Author's abstract of dissertation, Leningrad, 1968.

175. Makarov, P.O. Neyrodinamika zritel'noy sistemy cheloveka (Neurodynamics of the Optic System of Man). Leningrad, 1952.

176. Mogendovich, N.P. In the collection: Trudy Mosk. med. in-ta (Works of the Moscow Medical Institude). Vol. 6, No. 26, 1957, p. 3.

177. Mogil'nitskiy, M.S. In the collection: Trudy, posvyashch. 35-letiyu nauchn. deyat. prof. V.I. Voyacheka (Works Dedicated to the 35th Anniversary of the Scientific Work of Professor V.I. Voyachek). Leningrad, Vol. 2, 1936.

178. Molodkina, L.N. Fiziologicheskiy analiz eksperimental'nogo dvigatel'nogo nevroza, poluchayemogo metodom zvukovykh razdrazheniy (Physiological Analysis of Experimental Motor Neurosis, Produced by Sound Stimuli). Author's abstract of dissertation, Moscow, 1956.

179. Megun. The Awakening Brain. Translated from English, Moscow, 1965.

180. Myasnikov, A.L. Gipertonicheskaya Bolezn' (Hypertonic Disease). Moscow, 1954.

181. Myasnikov, A.L. Nekotoryye problemy gipertonicheskoy bolezni, ateroskleroza i koronarnoy nedostatochnosti i zadacha dal'neyshikh issledovaniy (Some Problems of Hypertonic Disease, Atherosclerosis and Coronary Insufficiency and the Task of Further Research). Moscow, Vol. 8, 1960.

182. Navyazhskiy, G.L. Ucheniye o shume (The Theory of Noise). Leningrad, 1948.

183. Nasonov, D.N. and K.S. Radvonik. Kokl. AN SSSR, Vol. 71, 1950, p. 5.

184. Nauman, A.G. Vibratsionnaya chuvstvitel'nost' (Vibration Sensitivity). Dissertation, Warsaw, 1914.

185. Naumova, T.S. Elektrofiziologicheskiy analiz mekhanizmov formirovaniya uslovnogo refleksa (Electrophysiological Analysis of the Mechanisms of Conditioned Reflex Formation). Leningrad, 1968.

186. Nestrugina, Z.F. Gig. truda, Vol. 3, 1964, p. 36.

187. Oka, S. Osnovy neyrofiziologii (Principles of Neurophysiology). Moscow, 1968.

188. Orlova, T.A. Gigiyenicheskaya otsenka shuma pri ispytanii vozdushnykh reaktivnykh dvigateley i mery po ogranicheniyu yego vozdeystviya (Hygiene Evaluation of Noise in Testing Jet Engines and Measures to Limit its Effect). Author's abstract of dissertation, Moscow, 1958.

189. Orlova, T.A. Problema bor'by s shumom na promyshlennykh predpriyatiyakh (The Problem of Controlling Noise in Industrial Plants). Moscow, 1965.

190. Orlova, T.A. and I.K. Razumov. In the collection: Mater. nauch. sessi po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Prevention of a Harmful Effect"). Leningrad, Vol. 97, 1968.

191. Orlova, T.A. and L.N. Sigalova. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trarazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Prevention of a Harmful Effect"). Leningrad, 1968.

192. Orlovskaya, E.P. Gig. i san., Vol. 4, 1961, p. 21.

193. Orlovskaya, E.P. Gigiyenicheskaya otsenka i normirovaniye vysokochastotnogo proizvodstvennogo shuma (Hygiene Evaluation and Standardization of High-Frequency Industrial Noise). Author's abstract of dissertation, Kiev, 1962a.

194. Orlovskaya, E.P. Gig. truda, Vol. 9, 1962b, p. 21.

195. Orlovskaya, E.P. Gig. i san., Vol. 5, 1963, p. 36.

196. Orlovskaya, E.P. Osobennosti deystviya preryvistogo (udarnogo) shuma r zlichnoy intensivnosti, voznikayushchego na shumovom fone Gig. truda (The Effect of Discontinuous (Impact) Noise of Varying Intensity, Developing Against a Noise Background. Industrial Hygiene). Kiev, 1967.

197. Pavlov, I.P. Poln. sobr. soch. (Complete Collected Works). Vol. 3, No. 2, 1951, p. 171.

198. Pavlova, Ye.B. Zhurn. vyssh. nervn. deyat., Vol. 15, 1957, p. 754.

199. Panauotti, Z.F. In the collection: Te. .sy dokl. 21-y otchetn. nauchn. konf. aspirantov i klinicheskikh ordinatorov LSGMI (Theses of Reports of the 21st Conference of Graduate Students and Clinical Interns of LSGMI). Leningrad, Vol. 18, 1961.

200. Panayutti, Z.F. In the collection: Trudy LSGMI (Works of the LSGMI). Leningrad, Vol. 75, 1963, p. 156.

201. Paskov, D.S. Nivalin. Farmakologiya i prilozheniye (Nivalin. Pharmacology and Application). Sofia, 1959.

202. Pilrovskiy, N.N. In the collection: Metodicheskiye voprosy izucheniya deystviya shuma na organizm (Methodological Questions of Studying the Effect of Noise on the Organism). Moscow, Vol. 47, 1963.

203. Pikrovskiy, N.N. Kompleksnoye izucheniye vliyaniya proizvodstvennykh shumov na slukh, tsentral'nuyu nervnuyu i serdechno-sosudistuyu sistemy (Complex Study of the Effect of Industrial Noises on Hearing, the Central Nervous and Cardio-Vascular Systems). Author's abstract of dissertation, Leningrad, 1968.

204. Popov, I.P. Vliyaniye shuma tovarnykh i frezernykh stankov na organizm podrostkov (The Effect of the Noise of Lathes and Milling Machines on the Organism of Adolescents). Author's abstract of dissertation, Irkutsk, 1967.

205. Popov, N.F. Gig. patologiya i bezopasnost' truda (Hygiene Pathology and Industrial Safety). Moscow, Vol. 4, 1929, p. 11.

206. Pratusevich, Yu.M. and N.N. Korzh. Gig. i san., Vol. 1, 1961, p. 44.

207. Pronin, A.P. Gig. i san., Vol. 11, 1965, p. 94.

208. Pronin, A.P. Issledovaniye proizvodstvennogo shuma na zavodakh zhelezobetonnykh konstruktsiy (A Study of Industrial Noise in Factories Making Ferroconcrete Structures). Author's abstract of dissertation, Leningrad, 1967.

209. Pronin, A.P. Issledovaniye proizvodstv. shuma na zavodakh zhelezobetonnykh konstruktsiy (A Study of Industrial Noise in Factories Making Ferroconcrete Structures). Author's abstract of dissertation, Leningrad, 1969.

210. Radzyukevich, T.M. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyanie ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on: "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Prevention of a Harmful Effect"). Leningrad, Vol. 111, 1968a.

211. Radzyukevich, T.M. In the collection: Tez dokl VI Vsesoyuzn. akustich. konf. (Theses of Reports to the 6th All-Union Acoustics Conference). Moscow, 1968b.

212. Radionova, Ye.A. Zhurn. vyssh. nervn. deyat., Vol. 15, No. 4, 1965, p. 739.

213. Razumov, I.K. Sposoby i organizatsiya bor'by s shumami i vibratsiyami na proizvodstve (Means and Organizations for Controlling Noises and Vibrations in Industry). Moscow, 1964.

214. Ramaccini Bernardino. O boleanyakh remeslennikov (On the Diseases of Workmen). Moscow, 1961.

215. Rakhmilevich, A.G. Shum i organ slukha (Noise and the Organ of Hearing). Moscow, 1964.

216. Reznikov, Ye.B. Fiziologo-gigienicheskaya otsenka shuma pri shtampovochnykh rabotakh (Physiological-Hygiene Evaluation of Noise in Stamping Operations). Author's abstract of dissertation, Leningrad, 1966.

217. Rzhevkin, S.N. Slukh i rech' (Hearing and Speech). Moscow, 1928.

218. Rzhevkin, S.N. Slukh i rech' v svete sovremennykh fizicheskikh issledovaniy (Hearing and Speech in the Light of Current Physical Studies). Leningrad, 1936.

219. Roytbak, A.I. In the collection: Trudy in-ta fiziologii AN Gruz. SSR. (Works of the Institute of Physiology, Academy of Sciences, Georgian SSR). Tbilisi, Vol. 10, 1956, p. 103.

220. Romm, S.Z. Professional'naya tugoukhost' (Occupational Deafness). Leningrad, 1966.

221. Romm, S.Z. and A.M. Vaynshteyn. Beregite slukh (Borderline Hearing). Leningrad, 1963.

222. Rossi, D. and A. Tsanketti. Retikulyarnaya formatsiya stvola mozga (The Reticular Formation of the Brain Stem). Moscow, 1960.

223. Rudenko, V.F. Shum pri ispytanii dizel'nykh motorov, yego neblagopriyatnoye vliyanie na organizm i puti profilaktiki (Noise in Testing Diesel Engines, Its Unfavorable Effect on the Organism and Ways of Prevention). Author's abstract of dissertation, Kharkov, 1963.

224. Rukavtsova, O.M. In the collection: Mater. XXVIII otchetnoy nauchn. konf. aspirantov i klinicheskikh ordinatorof LSGMI (Material of the 28th Scientific Conference of Graduate Students and Clinical Interns of LSGMI). Leningrad, 1968.

225. Rusinov. In the collection: Struktura i funktsii nervnoy sistemy (Structure and Functions of the Nervous System). Moscow, 1960.

226. Rusinova, A.P. Gig. truda, Vol. 10, 1963.

227. Rusinova, A.P. and L.P. Radionova. In the collection: Mater. nauchn. sessi po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednoyvo deystviya" (Material of the Scientific Conference on "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Prevention of a Harmful Effect:). Leningrad, 1968.

228. Rylova, M.L. Metody issledovaniya khronicheskogo deystviya vrednykh faktorov /299
sredy v eksperimente (Methods of Studying the Chronic Effect of Harmful Environmental Factors in Experiments). Leningrad, 1964.

229. Sakovich, F.S. Russk. otorinolar, Vol. 21, 1928, p. 515.

230. Samoylova, I.K. Probl. fiziol. akustiki, Vol. 4, 1959.

231. Sarkisov, S.A. Ocherki po strukture i funktsiyam mozga (Notes on the Structure and Function of the Brain). Moscow, 1964.

232. Svistunov, N.T. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyanie ucheniya o proizvod. shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystiviya" (Material on the Scientific Conference on "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Preventing a Harmful Effect"). Leningrad, Vol. 118, 1968.

233. Seletskaya, L.I. In the collection: Trudy in-ta biologicheskoy fiziki An SSSR (Works of the Institute of Biological Physics, Academy of Sciences USSR). Moscow, Vol. 178, 1955.

234. Simonov, P.V. Chto takoye emotsii? (What is Emotion?) Leningrad, 1966.

235. Skok, V.I. Vrach. delo., Vol. 11, 1964.

236. Skuratova, L.Ya. Shum na sudakh i mery bor'by s nim (Noise in Ships and Measures for Controlling It) Moscow, 1961.

237. Slavin, I.I. Izv. AN USSR, Vol. XIII, 1949, p. 6.

238. Slavin, I.I. Proizvodstvennyy shum i bor'ba s nim (Industrial Noise and Its Control). Leningrad, 1955a.

239. Slavin, I.I. Normy i pravila po ogranicheniyu shuma na proizvodstve (Standards and Rules for Organizing Noise in Industry). Leningrad, 1955b.

240. Slavin, I.I. Bor'ba s shumom na sudakh (Controlling Noise in Ships). Leningrad, 1955c.

241. Slavin, I.I. Proizvodstvennyy shum i bor'ba s nim (Industrial Noise and Its Control). Moscow, 1956.

242. Stivens, S.S. Eksperimental'naya psikhologiya (Experimental Psychology). Moscow, 1960.

243. Strakhov, A.B. Gig. i san., Vol. 4, 1964, p. 29.

244. Suvorov, G.A. K voprosy o vliyanii impul'snogo shuma na nekotoryye fiziologicheskiye funktsii organizma (On the Question of the Effect of pulse Noise on Several Physiological Functions of the Organism). Author's abstract of dissertation, Leningrad, 1965.

245. Suvorov, G.A. In the collection: Mater. VI Vsesoyuzn. akustich. konf. (Material of the 6th All-Union Acoustics Conference). Moscow, 1968.

246. Suvorov, G.A. Gig. truda, Vol. 9, 1969, p. 4.

247. Suvorov, G.A. and L.A. Marakushkin. Gig. i san., Vol. 7, 1970, p. 105.

248. Suvorov, G.A., Yu.M. Il'yashuk and A.M. Likhnitskiy. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvod. shum i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on: "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Preventing a Harmful Effect"). Leningrad, Vol. 124, 1968.

249. Temkin, Ya.S. Professional'naya glukhota (Occupational Deafness). Moscow, 1931.

250. Temkin, Ya.S. Glukhota i tugoukhost' (Deafness and Hardness of Hearing). Moscow, 1957.

251. Temkin, Ya.S. Professional'nyye bolezni i travmy ukha (Occupational Diseases and Ear Traumas). Moscow, 1968.

252. Tokarenko, I.I. In the collection: Trudy Donetskogo med. in-ta. (Works of the Donets Medical Institute). Donetsk, Vol. 19, 1961, p. 90.

253. Tokarenko, I.I. In the book: Regulyatsiya vegetativnykh funktsiy (Regulation of Autonomic Functions). Kiev, Vol. 95, 1965.

254. Trambitskiy, G.S. Russk. otorinolar., Vol. 2, 1925, p. 121.

255. Undrits, V.G. In the collection: Trudy 3-2c s"yezda otorinolaringologov (Works of the 3rd Conference of Otorhinolaryngologists). Leningrad, Vol. 29, 1935.

256. Uroda, P.S. Vestn. otorinolar., Vol. 1, 1929, p. 82.

257. Ukhtomskiy, A.A. Vozbuzhdeniye, tormozheniye, utomleniye (Excitation, Inhibition, Fatigue, Collected Works). Vol. II, Leningrad, 1951.

258. Kahymovich, M.L. Gig. i san., Vol. 9. 1960, p. 32.

259. Khaymovich, M.L. Vliyaniye vysokochastotnogo proizvodstvennogo shuma na sostoyaniye nekotorykh funktsiy organizma (The Effect of High-Frequency Industrial Noise on the State of Several Functions of the Organism). Author's abstract of dissertation, Leningrad, 1961.

260. Chuchumov, M.A. In the collection: Tezisy dokl. obl. nauchno-prakt. konf. po probleme: "Vliyaniye proizv. travmat. i mery profilaktiki" (Theses of Reports of the Regional Scientific and Practical Conference on the Problem: "The Effect of Industrial Traumatism and Preventative Measures"). Saratov, Vol. 11, 1965.

261. Shatalov, N.N., V.Ye. Ostapkovich and N.I. Ponomareva. In the collection: Mater. nauchn. sessii po probleme: "Sovr. sostoyaniye ucheniya o proizvodstvennom shume i ul'trazvuke, ikh vliyanii na organizm i profilaktike vrednogo deystviya" (Material of the Scientific Conference on: "The Present State of the Theory of Industrial Noise and Ultrasonics, Their Effect on the Organism and Preventing a Harmful Effect"). Leningrad, Vol. 132, 1968.

262. Sheyvekhman, B.Ye. In the collection: Tez. dokl. 4-go soveshch. po fiziol. problemam: "Fiziologiya organov chuvstv" (Theses of Reports of the 4th Conference on Physiological Problems: "The Physiology of Sense Organs"). Moscow, Vol. 23, 1938.

263. Shepelin, O.P. In the collection: Trudy LSGMI (Works of the LSGMI). Leningrad, Vol. 58, 1959.

264. Shepelin, O.P. Gig. i san., Vol. 3, 1961, p. 18.

265. Shkarinov, L.N. Gigiyenicheskaya otsenka proizvodstvennogo shuma i osnovnyye puti /300
profilaktiki yego neblagopriyatnogo vozdeystviya (Hygiene Evaluation of Industrial Noise and Principal Ways of Preventing Its Unfavorable Effect). Moscow, 1964.

266. Shklovskiy, M.A. Klassifikatsiya i differentsial'naya diagnostika rasstroystva slukha i rechi (Classification and Differentiation Diagnostics of Hearing and Speech Disorders). Moscow, 1939.

267. Shreder, K. In the collection: Trudy nauchn. konf. Len. in-ta okhrany truda (Works of the Scientific Conference of the Leningrad Institute of Industrial Safety), 21 - 25 August, 1956, Leningrad, Vol. 49, 1958.

268. Yakovlev, P.A. Vestn. oftal'mol., Vol. 17, 1940, p. 4.

269. Adrian, E. The Mechanism of Nervous Action. Philadelphia, Vol. 23, 1932.

270. Adrian, E. and A. Matthews. Brain. Vol. 57, 1934, p. 355.

271. Adrian, E. J. Physiol., Vol. 89, No. 1, 1937, p. 1.

272. Angeluscheff, H. Acta otolaring., Vol. 46, 1956, p. 5; Pract. otorhinolaring., Vol. 21, 1959, p. 3.

273. Allen, C.K. and A.S. Potter. Sound Uses and Control, Vol. 1, No. 1. 1962, p. 34.

274. Apostolof, Ch. Rev. roumaine biol., Ser. Zool., Vol. 10, No. 3, 1965, p. 191.

275. Bauch, H. Acustica, Vol. 6, 1956; Supplement, Vol. 2, p. 494.

276. Barberi, G. Ann. laring., Vol. 5, 1958, p. 516.

277. Békésy, G. Physikal. Z., Vol. 21, 1929, p. 721.

278. Békésy, G. J. Ac. Soc. Am., Vol. 19, 1947, p. 452; Vol. 21, 1949, p. 245; Vol. 236, 1957, p. 56.

279. Bell, Alan. Noise. World Health Organization. Geneva, 1967.

280. Bell, A. Noise — Occupational Damage and Public Harm. Moscow, 1967.

281. Beranek, L.L. and H.P. Sleeper. J. Ac. Soc. Am., Vol. 18, 1946, p. 140.

282. Bevan, W. Percept. and Motor Skills, Vol. 20, 1965, p. 269.

283. Bradley, P.B. In: Psychotropic Drugs. Amsterdam, Vol. 193, 1957.

284. Bradley, P. and B. Key. Electroenceph. clin. Neurophysiol., Vol. 10, No. 1, 1958, p. 97.

285. Broadbent, D.E. Percept. and Communication. London, 1958.

286. Bruhl, G.Z. Hals-, Nas-, and Ohrenheilk., Vol. 52, 1906, p. 230.

287. Bugard, P. Presse med., Vol. 63, No. 34, 1955, p. 493.

288. Bugard, P. Arch. Mal. profess., Vol. 19, No. 1, 1958, p. 21.

289. Bugard, P. and H. Sauvras, Med. acronautigue, Vol. 8, No. 1, 1953, p. 78.

290. Bugard, P., H. Souvras and J.C.R. Salle. Soc. Biol., Vol. 147, 1957.

291. Burns, W. Trans. Ass. Industr. Med. Officers, Vol. 15, 1965, p. 2.

292. Calin Daud. Science, Vol. 149, No. 3685, 1965, p. 761.

293. Chaba working group 46. National Research Council, Committee on Hearing, Bio-acoustics and Biomechanics. Hazardous Exposure to Intermittent and Steady-State Noise. Washington, 1965.

294. Chang, H. In the collection: Problems of Contemporary Physiology of the Nervous and Muscle System. Tbilisi, Vol. 43, 1956.

295. Chisman, J.A. and J.R. Simon. J. appl. Psychol., Vol. 45, 1961, p. 402.

296. Cibert, A.P. and others. Rev. corps sante sante armées terre mer, air, Vol. 7, No. 5, 1966, p. 707.

297. Cohen, A. Am. Industr. Hyg. Ass. J., Vol. 24, No. 3, 1963, p. 227.

298. Coles, R.R.A. and C.G. Rice. J. Sound Vibration, Vol. 4, 1966, p. 172.

299. Coles, R.R.A., G.R. Garinter, D.C. Hodge and C.G. Rice. J. Ac. Soc. Am., Vol. 43, No. 2, 1968, p. 336.

300. Collucci, C. Atti della R. Acad. Med. Chir. di Napoli, Vol. LXX, 1926, p. 111.

301. Costa, L.D., H.G. Vanghan and L. Gilden. Percept. and Motor Skills, Vol. 20, 1965, p. 771.

302. Cremer, L. Acustike, Vol. 2, 1951, p. 83.

303. Crulman, C.D. J. Ac. Soc. Am., Vol. 33, 1961, p. 89.

304. Dennier, A. Arch. Mal. profess., Vol. 20, No. 5, 1959, p. 640.

305. Dieroff, H.G. Arch. Orh-, Nas.- and Kehlk. Heilk., Vol. 178, 1961; Vol. 179 and 409, 1962.

306. Doughty, I.M. and W.R. Garner. J. exp. Psychol., Vol. 37, 1947, p. 351.

307. Dunlap. Palmesthetic Difference Sensibility for Rate. J. Physiol., Vol. 29, 1913, p. 108.

308. Eccles, J.C. Pharmacol exp. Ther., Vol. 118, 1956, p. 26.

309. Erhard. Cited by A.G. Nauman, 1914.

310. Faleg, C. and F. Angeleri. Ann. Otol., Vol. 57, No. 6, 1958, p. 635.

311. Feldtkeller, R. and R. Oetinger. Acustica, 1956, Supplement 2, p. 489.

312. Fletcher, H. Rev. med. Phys., Vol. 12, 1940, p. 47.

313. Fletcher, H. and A.J. Riopelle. J. Ac. Soc. Am., Vol. 32, 1960, p. 401.

314. Fowler, E. Arch. otolaring., Vol. 24, 1936, p. 731.

315. Frandjedu, E. Z. Preventiv med., Vol. 4, 1959, p. 1.

316. Frings, H. J. Ac. Soc. Am., Vol. 24, No. 2, 1952, p. 163.

317. Frolik, I. Scientific Reports on Industrial Hygiene and Occupational Diseases. Prague, Vol. 6, 1961, p. 16.

318. Fusko, M., C. D'Amoco, C. Collucci and R. Fimiani. Folia med., Vol. 48, No. 2, 1965, p. 88.

319. Galambos, R., A. Schwartzkopf and A. Rupert. Am. J. Physiol., Vol. 197, 1959, p. 527.

320. Galin, D. Science, Vol. 149, No. 3685, 1965, p. 761.

321. Gassler, C. Acustica, Vol. 4, 1954, Supplement 1, p. 408.

322. Gastaut, H. Electroenceph. clin. Neurophysiol., Vol. 2, No. 3, 1950, p. 249.

323. Gault, R. J. Frankl. Inst., Vol. 209, 1930; Ann. Psychol., Vol. 34, 1934; J. Ac. Soc. Am., Vol. 8, 1936, p. 1.

324. Gilmer, H. J. Gen. Psychol., Vol. XIII, 1935, p. 1; J. exp. Psychol., Vol. XXI, 1937, p. 456; Psych. Bull., Vol. 8, 1939, p. 32.

325. Gierke, H.E. J. Ac. Soc. Am., Vol. 39, 1966, p. 543.

326. Glorig, A. Laryngoscope, Vol. 68, 1958, p. 447.

327. Glorig, A., W.D. Ward and J. Nixon. Arch. otolaryng., Vol. 74, 1961, p. 413.

328. Goldstein, M.H., N. Kianga and R.M. Brown. J. Ac. Soc. Am., Vol. 31, 1959.

329. Goodfellow, L. Psych. Bull., Vol. 33, 1936, p. 775.

330. Hall, G.S. and P. Kries. Arch. Physiol., Vol. 1879, Supplement 1.

331. Hardesty, D. and W. Bevan. Psychol. Rec., Vol. 15, 1965, p. 385.

332. Hardy, H.C. J. Ac. Soc. Am., Vol. 24, 1956, p. 756.

333. Hirsh, I. J. Ac. Soc. Am., Vol. 31, 1962.

334. Hirsh, I.F. and R.C. Bilger. J. Ac. Soc. Am., Vol. 27, 1955, p. 1186.

335. Hodge, D.C. J. Ac. Soc. Am., Vol. 37, 1965, p. 1194.

336. Hodge, D.C., R.B. McCommons and R.F. Blackmer. J. Auditory Res., Vol. 6, 1966, p. 121.

337. Hodge, D.C. and R.B. McCommons. J. Ac. Soc. Am., Vol. 40, 1966, p. 839.

338. Hoessli, C. Z. Ohrenheilk, Vol . 60, 1913.

339. Horak, F. Physiol. bohemasl., Vol. 14, No. 5, 1965, p. 495.

340. Jansen, G. Arch. Gewerbepath., Vol. 17, 1959, p. 238; Med. Welt, Vol. 1, 1960, p. 57.

341. Jansen, G. and T. Rey. Z. ang. Physiol., Vol. 4, 1962, p. 12.

342. Jansen, G. and M. Mattias. Z. ang. Physiol., Vol. 19, 1962, p. 8.

343. Jasper, H. J. Ges. Psychol., Vol. 14, No. 1, 1936, p. 98.

344. Jasper, H. In: Brain Mechanisms and Consciousness. A. Symposium. Oxford, 1956, p. 374.

345. Knudsen, V. Phys. Rev., Vol. 21, 1923, p. 84.

346. Knudsen, V. J. gen. Psychol., Vol. 12, 1928, p. 330.

347. Kobrick, J.L. J. Eng. Psychol., Vol. 4, 1965, p. 1.

348. Kryter, R.D. Noise Control, September, Vol. 6, 1960, p. 12.

349. Kryter, K.D. J. Ac. Soc. Am., Vol. 35, 1963, p. 1515.

350. Kryter, K.D. Am. Indsr. Hyg. Ass. J., Vol. 26, 1965, p. 34.

351. Kryter, K.D. and G.R. Garinther. Acta Otolaryng., Supplement 221, 1965.

352. Kryter, K.D., W.D. Ward, J.D. Miller and D.J. Eldredge. Ac. Soc. Am., Vol. 39, 1966, p. 451.

353. Langenbeck, B. Questions of Practical Audiometry. Stuttgart, 1956.

354. Langenbeck, B. Acta otolaring., Vol. 51, 1960, p. 295.

355. Laverge, I. Arch. Mal. profess., Vol. 23, No. 10 - 11, 1962, p. 697.

356. Lehmann, G. Physik. Blatter, Vol. 12, 1956, p. 554.

357. Lehmann, G. and J. Tamm. J. Ac. Soc. Am., Vol. 18, 1946.

358. Lehmann, G. and I. Tamm. Intern. Z. ang. Physiol., Vol. 16, 1956, p. 217.

359. Licklider, I.C.R. In: Handbook of Exp. Psychology, Vol. 985, p. 1951.

360. Mark, R.E. Med. Klin., Vol. 11, 1960, p. 409.

361. Mattias, H. and G. Jansen. Arbeitsphysiologie, Vol. 19, 1962, p. 201.

362. Mayer, A. Phil. Mag., Vol. 2, 1876, p. 500.

363. Meyer-Delius. I. Automobiltechnische Z., Berlin, Vol. 59, 1957, p. 10.

364. Miller, G.A. J. Ac. Soc. Am., Vol. 19, 1947, p. 609 and 798.

365. Miller, G.A. and G. Taylor. J. Ac. Soc. Am., Vol. 20, No. 2, 1948, p. 171.

366. Mizukoshion. Ann. Otol., Vol. 66, 1957, p. 1.

367. Morison, R. and E. Dempsey. Am. J. Physiol., Vol. 135, 1942, p. 281.

368. Niese, H. High Frequency Technology and Electroacoustics. Vol. 72, No. 1, 1963, p. 3.

369. Oetinger, R. Excitation of the Hearing Apparatus by Continuous Noise and Short Pulses, HTZ. Vol. 12, 1959, p. 391.

370. Ostmann. In: Handbook of Ear Therapy, B. Vol. 462, 1909.

371. Paracelsus. (Philippus Theophrastus; Bombastus von Hohenheim). Complete Works, Munich-B., Vol. 1 - 14, 1922 - 1933.

372. Pearson, A. Arch. Neurol. and Psych., Vol. 20, 1928.

373. Pfander, F. Cited by R.R. Goles, et al., 1968.

374. Pierson, H. In: The Sensations: Their Functions, Processes and Mechanisms. London, Vol. 227, 1952.

375. Pitts, H., H. Magoun and S. Ranson. Am. J. Physiol., Vol. 126, No. 3, 1939, p. 673.

376. Plompp, R. and M.A. Bouman. J. Ac. Soc. Am., Vol. 31, 1959, p. 748.

377. Pollack, I. J. Ac. Soc. Am., Vol. 23, 1951; Am. J. Psychol., Vol. 65, 1952, p. 4.

378. Prolingheuer, H.K. Occupational Medicine and Accident Prevention. Vol. 6, No. 6, 1956, p. 128.

379. Purella, F. Folia med., Vol. 1, 1958, p. 16.

380. Rinaldi, F. and H. Himwich. Ann. N.Y. Acad. Sci., Vol. 61, 1955, p. 27.

381. Roberts, W.A. J. Frankl. Inst., Vol. 213, 1932, p. 3.

382. Rol, C. Cited by A. Bell, 1967.

383. Rose, M. J. Psych. and Neurol., Vol. 45, No. 4, 1933, p. 5.

384. Rosenberg. Otorinolaryng. Vol. 1, 1956, p. 45.

385. Rosenblith, W.A. and K.C. Stevart. Am. Industr. Hyg. Ass. J., Vol. 18, No. 3, 1957, p. 227.

386. Rothballer, H.B. Electroenceph. clin. Neurophysiol., Vol. 8, 1956, p. 603.

387. Ruedi. L. Acta otolaring., Vol. 41, 1952, p. 150.

388. Saito, K. Jap. J. Publ. Hlth. Vol. 11, No. 4, 1964a, p. 153; Vol. 11, No. 5, 1964b, p. 445.

389. Salonna, F. Riv. Audiol. prat., Vol. 7, 1957, p. 2.

390. Scal, H.Y. J. Med., Vol. 18, 1956, p. 2839.

391. Scholl, H. J. Ac. Soc. Am., Vol. 2, 1962, p. 91 and 101.

392. Selters, W. J. Ac. Soc. Am., Vol. 35, 1963, p. 99.

393. Servit. Cited by G.M. Krivitskiy, 1964.

394. Simmons, F.B. Ann. Otol., Vol. 68, 1959, p. 1126.

395. Spieth, W. and W. Trittipoe. J. Ac. Soc. Am., Vol. 30, 1958, p. 6.

396. Sujuki, K. et al. J. exp. Med., Vol. 69, No. 1, 1958, p. 25.

397. Symanski. Z. arzt. Forbildung., Vol. 23, 1959, p. 1277.

398. Thurlow, W.R. and A.M. Small. J. Ac. Soc. Am., Vol. 27, 1955, p. 132.

399. Thurlow, W.R. and R.J. Bowman. J. Ac. Soc. Am., Vol. 29, No. 2, 1957, p. 281.

400. Titeca, J. Acta neurol. et psychiat., Belg., Vol. 65, No. 8, 1965, p. 598.

401. Tolof, F. and Rety. Arch. Mal. profess., Vol. 20, No. 5, 1954, p. 625.

402. Tomatis, M. Med. Aeronaut., Vol. 14, No. 2, 1959, p. 163.

403. Trittipoe, W. J. Ac. Soc. Am., Vol. 30, 1958, p. 250.

404. Urbantschitsch, V. Arch. ges. Physiol., Vol. 42, 1888, p. 152.

405. Ward, W.D. J. Ac. Soc. Am., Vol. 34, 1962a, p. 1132; Vol. 34, 1962b, p. 1610.

406. Ward, W.D., A. Glorig and D. Sklar. J. Ac. Soc. Am., Vol. 30, 1958, p. 944.

407. Ward, W.D., A. Glorig and W. Selters. J. Ac. Soc. Am., Vol. 32, No. 235, 1960, p. 791.

408. Wegel, R. and C. Lane. Phys. Rev., Vol. 23, 1924, p. 266.

409. Wheeler, D.E. Arch. Otolaring., Vol. 51, 1950, p. 344.

410. Wittmaack, K. Arch. Ohr.- Nas.- and Kehlk. Heilk, Vol. 123, 1929, p. 49.

411. Zange. J. Arch. Ohrenheilk., Vol. 86, 1911, p. 167.

412. Zwicker, E. and O. Gassler. Acustica, Vol. 2, 1952, Supplement 3, p. 134.

413. Zwicker, E. Acustica, Vol. 6, 1956, Supplement 2, p. 365; Vol. 8, 1958, Supplement 1, p. 237.

Translated for National Aeronautics and Space Administration under contract No. NASw 2035, by SCITRAN, P. O. Box 5456, Santa Barbara, California, 93108.